

**Shell Chukchi Sea Outer Continental Shelf Lease
Exploration Plan Revision 2
Environmental Impact Assessment – Attachment A
Arctic Offshore Air Quality Impacts
Recommendations for Appropriate Criteria
for Determining Significance Under NEPA**

Executive Summary

The Bureau of Ocean Energy Management (BOEM) is charged with evaluating the impacts of air emissions associated with oil and gas exploration activities on the Outer Continental Shelf (OCS) under two different statutory/regulatory programs: (1) compliance with BOEM's Air Quality Regulatory Program (AQRP) (which addresses onshore impacts of emissions from OCS sources), and (2) the "hard look" at potential environmental impacts required for every major federal action under the National Environmental Policy Act (NEPA). Section 7.0 of the Revised Outer Continental Shelf Lease Exploration Plan, Chukchi Sea, Alaska (EP Revision 2) demonstrates that Shell's proposed operations are exempt from further air quality review under the terms of BOEM's AQRP because the relevant emissions impacts onshore are negligible, requiring no further analysis for purposes of agency review of EP Revision 2. In its NEPA analysis of Shell's prior exploration plans, BOEM utilized the analyses of air quality impacts prepared in support of the Clean Air Act permits Shell obtained from the Environmental Protection Agency (EPA). Because Congress has now changed jurisdiction for protection of air quality in the OCS offshore of the North Slope Borough of Alaska from the EPA to BOEM and Shell will not have a Clean Air Act permit from EPA, air quality impacts will no longer be analyzed under EPA procedures and standards. As such, BOEM now has an opportunity to identify an appropriate methodology to evaluate air quality impacts for potential significance under NEPA.

In the past, BOEM in Alaska established NEPA significance thresholds for onshore air quality impacts based upon Clean Air Act standards, including the National Ambient Air Quality Standards (NAAQS) and the Prevention of Significant Deterioration (PSD) increments. See, e.g., BOEM, Environmental Assessment for Shell's 2011 Revised Chukchi Sea Exploration Plan (OCS EIS/EA BOEM 2011-061, Dec. 2011) (EA for EP Revision 1), Appendix B. These standards may continue to be applicable in the onshore environment as "significant impact" criteria under NEPA. But, while BOEM formerly used the NAAQS and PSD increments as default indicators of NEPA significance in the Arctic offshore environment, reference to those EPA standards is not necessary under NEPA because of the remoteness of the emissions sources and the very limited exposure of humans to project emissions in the offshore. Specifically, the NAAQS were established by the EPA to protect nationwide air quality in areas reasonably accessible to the general public, in order to protect the health of the most vulnerable population and to protect the quality of the environment generally.^a Because emissions from Shell's project will impact only remote and inaccessible offshore areas, where comparatively healthy people are present, if at all, only for limited periods of time and receptors in the ecosystem are transient, the NAAQS are not appropriate benchmarks for use in BOEM's analysis of the offshore air quality impacts of Shell's proposed operations in the Chukchi Sea.

^a 42 USC § 7409, U.S. Clean Air Act: national primary and secondary ambient air quality standards.

This document defines a set of more suitable offshore criteria to protect the health of the limited numbers of persons who work in offshore Arctic Ocean areas as well as subsistence hunters and fishermen in the Chukchi Sea, a few of whom may occasionally encounter some ancillary aspect of Shell's operations.^b Shell developed these criteria after reviewing scientific evidence and Occupational Safety and Health Administration (OSHA) state and federal standards. The criteria adopted are more protective than OSHA's exposure standards, and thus have a built-in margin of safety. They represent proposed maximum concentration limits for Shell's operations. The criteria are set at levels adequate to ensure no significant impacts on the health of exposed workers and subsistence hunters and fishermen (if any), and are also not expected to cause significant impacts to marine life and other environmental resources present in the offshore regions of the Arctic Ocean. These criteria for significant offshore air quality impacts are as follows:

- PM_{2.5} and PM₁₀: 500 µg/m³ (1-hour average concentration, not to be exceeded)
- NO₂: 3,760 µg/m³ (2 ppm) (1-hour average concentration, not to be exceeded)
- CO: 55,000 µg/m³ (50 ppm) (1-hour average concentration, not to be exceeded)
- SO₂: 5,200 µg/m³ (2 ppm) (1-hour average concentration, not to be exceeded)

Assuming emissions from Shell's operations would not cause an exceedance of any of these criteria at offshore locations where third-party boats and vessels may experience emissions from the project, the emissions would be deemed not to have a significant impact requiring preparation of an Environmental Impact Statement.

Analysis

1. BOEM Needs to Determine Independent Criteria for NEPA Significance

Now that Congress has transferred from EPA to BOEM jurisdiction for air quality impacts on the OCS offshore of the North Slope Borough of Alaska, BOEM must develop an appropriate method for its NEPA analysis of those impacts. In the past, BOEM has used the analyses performed for EPA permits to inform its NEPA analysis of Shell's Alaska air quality impacts, but EPA analyses will no longer be available or appropriate for BOEM's use.

Shell expects that BOEM will continue to apply the Clean Air Act-based criteria it has developed in the past to determine whether and under what control scenarios Shell's air emissions will have a significant impact on onshore air quality for purposes of NEPA. Those criteria will remain keyed to the NAAQS applicable to the onshore area and the increment (or some fraction thereof) that would be applicable to the source if it were still regulated by EPA under its PSD rules. Going forward, the most significant change will be in how offshore air impacts are evaluated for significance under NEPA, *i.e.*, whether a project's estimated air emissions will have a "significant" impact such that an Environmental Impact Statement is required under NEPA.

Onshore Emissions

BOEM's current approach to determining "significance" of onshore emissions is exemplified in BOEM's EA for EP Revision 2.. In that EA, BOEM evaluated projected onshore and offshore air quality impacts

^b Subsistence hunting and fishing rarely, if ever, take place more than 30 miles offshore. The *Discoverer* and *Polar Pioneer* will operate more than twice that far offshore. Any project-related emissions that persons may encounter will almost certainly be limited to emissions from supply boats transiting to or from the *Discoverer* and *Polar Pioneer*. Shell accordingly believes that compliance with the proposed air quality limits should be evaluated only at points located within the subsistence areas designated under Figure 3.11.6-11 in the EIA for EP Revision 2.

from Shell’s project against applicable NAAQS, while also examining whether in any case air quality impacts from Shell’s emissions would exceed 50 percent of either the NAAQS or the “maximum allowable increase,” i.e., the applicable PSD increment. EA at 67-68, Tables 28 and 29. BOEM concluded that the proposed action would be “compliant with the federal air quality standards and without potential to cause or contribute to any violation of the NAAQS, which define healthful outside air quality. . . . As such, the level of effect on air quality caused by the Proposed Action is considered minor” Id. at 70-71.^c BOEM has provided further clarification on determination of the significance levels of onshore emissions for the Chukchi Lease Sale 193 area. Under the Supplemental Environmental Impact Statement for Lease Sale 193 (OCS EIS/EA BOEMRE 2011-041, Nov. 2011), BOEM determined a significant effect when the project-related emissions cause an increase in pollutant concentrations over the nearest onshore area of at least 20 square kilometers that exceed 50 percent of NAAQS and maximum allowable increases (MAIs).

Offshore Emissions

While the significance levels BOEM developed for air quality impacts in the onshore environment may remain applicable to onshore impacts, Congress’s decision to change jurisdiction for OCS air quality impacts offshore of the North Slope Borough from EPA to BOEM makes it necessary for BOEM to update its methodology for evaluating offshore air impacts. Clean Air Act Section 328(b) requires only that BOEM “coordinate” air pollution control regulations for OCS sources and adjacent onshore areas. In contrast, Section 328(a) requires EPA to regulate OCS sources specifically to “attain and maintain” the NAAQS and to comply with subchapter I of the Clean Air Act (stationary source requirements). Because Congress chose in Section 328(b) not to require that sources in areas of the OCS administered by BOEM meet the NAAQS and the Clean Air Act (CAA) stationary source provisions, BOEM has both the discretion and obligation to thoughtfully regulate OCS sources within its jurisdiction, independent of these EPA standards. To assist BOEM with the NEPA analysis, Shell has developed proposed standards of NEPA significance that are more appropriate to the offshore environment and to the small population of workers in the region and subsistence hunters who might be briefly exposed at offshore locations to the air quality impacts from the project.

2. Clean Air Act Standards Are Not Appropriate Thresholds for Offshore NEPA Significance Levels

The NEPA significance levels BOEM has used for onshore analysis are not appropriate for offshore analysis in the Arctic for several reasons. First, as discussed in detail below, the NAAQS, on which the significance levels rely, were designed for areas accessible to the public, and do not provide meaningful information on the significance of air quality impacts upon a remote and inaccessible region such as the Chukchi Sea OCS. Second, the impacts of offshore emissions to the human and natural environment offshore will be different from the impacts to the onshore environment because the affected environment is different. Third, information on background air quality is different onshore versus offshore. Finally, and most important, both the human and fauna populations offshore are transient, and thus are extremely unlikely to remain in a fixed location exposed to air pollution for the duration of a day, let alone a full drilling season.

^c For air quality impacts, BOEM’s NEPA “significance threshold” is that the project’s emissions would cause at an onshore location (1) a violation of a NAAQS or (2) an increase in pollutant concentrations that would (a) exceed half of any NAAQS except for ozone, (b) exceed half of the maximum allowable increase (increment) under EPA’s PSD rules, or (c) exceed half of the ozone NAAQS including precursor emissions of VOCs and NOX. EA, App. B at B-1.

A. NAAQS Are Broad Nationwide Standards With Limited Relevance to Arctic OCS Operations

Some advocacy groups have suggested that BOEM should apply Clean Air Act standards, such as the NAAQS, in its NEPA analysis of the offshore air quality impacts of Shell's proposed Chukchi Sea operations. However, those Clean Air Act standards are not legally binding on BOEM as applied to the Arctic offshore region^d and, more important, are not designed for an environment such as the Arctic Ocean. The CAA and its amendments mandated uniform nation-wide standards that are designed to protect public health and welfare everywhere in the United States. The CAA promotes the implementation of air quality controls to limit the exposure of the general public to unhealthy concentrations of pollutants in the air. The keystone of the CAA as originally enacted was Title I, Part A, Section 109, which established NAAQS. The NAAQS are designed to provide a set of concentration criteria to protect the public health and public welfare with a margin of safety. The CAA defines the NAAQS as a set of "primary" standards that are implemented to protect human health, and "secondary" standards that protect the general welfare. The CAA required EPA to establish NAAQS based on current scientific knowledge and studies and to update the NAAQS on a five-year schedule to incorporate new information.

B. EPA's Definition of Ambient Air is Not Appropriate for Remote OCS Operations

The primary NAAQS are ambient air pollution concentration thresholds that should not be surpassed in areas accessible to the general public. The CAA does not define "ambient air" or the "general public," leaving the definition and interpretation of these terms to the enforcing agency to allow flexibility in its implementation. EPA adopted the following definition of ambient air: "*Ambient air* means the portion of the atmosphere, external to buildings, to which the general public has access." 40 CFR 50.1(e).

EPA has interpreted the phrase "to which the general public has access" through a series of official memoranda and policy statements. These policy documents exempt that portion of the atmosphere over land that is controlled by a source where public access is precluded by a fence or other physical barrier.^{e,f} Ambient air is further limited by applying the NAAQS standards only to the portion of the atmosphere near ground level and building rooftop level, where the general public can reside. If the definition of ambient air were expanded to include all regions of the atmosphere that members of the public could theoretically access, even for short periods of time, air pollution control would be economically unfeasible. For example, the air aloft is accessible to the general public via aircraft, but the exposure period at any given point in a moving vehicle is limited and short compared to the health-based exposure periods recognized in the NAAQS. Thus, to balance the need for economic activity with the protection of human health, EPA has necessarily used common sense in interpreting its definition of ambient air, with recognition that even though access to a given area may not be absolutely impossible, that area cannot reasonably be considered ambient air.

In making case-by-case determinations of what is ambient air under the CAA, EPA and state agencies have struggled with applying the definition of "ambient air" over water. While EPA has determined that atmosphere over bodies of water reasonably accessible to the general public can fall within the agency's definition of ambient air, the Alaska Department of Environmental Conservation (ADEC) has recognized that certain bodies of water and other geophysical barriers, if not reasonably accessible to the public, can represent a physical barrier that precludes public access.^g The U.S. Court of Appeals for the Ninth Circuit

^d 42 USC § 7627(b).

^e USEPA, Region I-IX Meteorologists, "Regional Meteorologists' Memorandum," dated May 16, 1985.

^f *Resisting Environmental Destruction on Indigenous Lands v. EPA*, 704 F.3d 743, 753 (9th Cir. 2012) (*REDOIL*).

^g ADEC Modeling Review Procedures Manual, Section 3.3, Sept. 14, 2011.

concurred, finding that it was “just common sense” that the agency be allowed some “leeway” in applying its land-based ambient air definition to overwater situations.^h

The offshore region of the Chukchi Sea is not under EPA’s jurisdiction and the marine environment represents a formidable geographic barrier that limits reasonable access to the general public. The population that does access the offshore regions of the Chukchi Sea consists almost entirely of marine-vessel occupants and subsistence hunters. Both of these populations are transient groups that access any point of the offshore region (usually not more than 30 miles offshore) only briefly. The NAAQS primary standards were established to protect the health of the most vulnerable members of the general public, not persons temporarily working or engaged in hunting and fishing offshore in the Chukchi Sea. Therefore, the NAAQS are not the appropriate standards to promote public health and public welfare in these offshore areas of the Chukchi Sea, and BOEM should not apply them in determining the significance of offshore air impacts.

EPA’s recent update of the 1-hour NAAQS for nitrogen dioxide (NO₂) illustrates key differences between the exposure data EPA uses to set NAAQS under the CAA and the impact review BOEM is required to conduct under NEPA, and therefore why NAAQS are not appropriate criteria for BOEM’s NEPA review. First, in setting the new NO₂ standard EPA cited findings that “traffic-related exposures can dominate personal exposures to NO₂,” that “[w]hile driving, personal exposure concentrations in the cabin of a vehicle could be substantially higher than ambient concentrations measured nearby,” and that concentrations of nitrogen oxides (NO_x), as well as carbon monoxide and ultrafine particulate matter (PM), “typically display peak concentrations on or immediately adjacent to roads.”ⁱ These largely urban exposure scenarios do not exist in the Arctic OCS. Second, EPA set the standard to protect sensitive groups in the population, noting that “subpopulations considered potentially more susceptible to the effects of NO₂ exposure included persons with pre-existing respiratory disease, children, and the elderly.”^j It is unlikely that children, the elderly, and those with respiratory disease will be in the vicinity of the activities BOEM is reviewing.

C. Use of NAAQS for Offshore Significance Determinations is Not Consistent with BOEM’s Current Regulatory Approach

Air quality impacts attributable to oil and gas activities on the Outer Continental Shelf in portions of the Gulf of Mexico and offshore of the North Slope Borough of Alaska are governed by CAA Section 328(b), which instructs the Secretary of the Interior to “assure coordination of air pollution control regulation for Outer Continental Shelf Emissions and emissions in the onshore adjacent areas.”^k BOEM has managed oil and gas emissions in the Gulf of Mexico under this standard for over twenty years, and now has jurisdiction for the area of the Outer Continental Shelf offshore of the North Slope Borough of Alaska.

BOEM has not applied a project-specific NAAQS analysis in its review of air quality impacts in the Gulf of Mexico. However, BOEM has enforced air quality limitations on offshore sources to ensure protection of NAAQS onshore. This policy is consistent with a position that the offshore region is relatively inaccessible to the general public. Much of the region is frequented by marine traffic, but it is generally recognized that this population is transient and, as a result, the exposure periods considered in the NAAQS are not applicable. The reasoning behind the Gulf of Mexico exemption applies with even greater force in the Arctic Ocean given inherent limits on access due to remoteness and climatic extremes.

^h *REDOIL*, 704 F.3d at 753.

ⁱ 75 Fed. Reg. 6479 (Feb. 9, 2010), citing “Integrated Science Assessment for Oxides of Nitrogen-Health Criteria,” Section 2.5 (EPA, 2007).

^j 75 Fed. Reg. 6480 (Feb. 9, 2010).

^k 42 USC § 7627(b).

D. Using Clean Air Act Standards Would Compromise BOEM's NEPA Analyses

For the reasons outlined above, the CAA and Alaska onshore air quality standards are not applicable nor are they appropriate to assess offshore air quality impacts under NEPA. The NAAQS and PSD increment limits are national standards that EPA applies to onshore (and some offshore) areas. EPA has no flexibility in applying the NAAQS and applicable increments; they are one-size-fits-all national standards. NAAQS and increments are appropriate to EPA's statutory responsibilities under the Clean Air Act and may be acceptable proxies for determining the significance of OCS source emissions at onshore locations.

Were the NAAQS standards used as threshold criteria to define significant impacts to OCS air quality under NEPA, that approach actually would undermine BOEM's effort to realistically assess these offshore environmental impacts. BOEM's responsibility is to conduct a rigorous analysis of whether air quality impacts will be significant in a specific affected environment (here, the Burger Prospect some 60 miles offshore which hosts limited numbers of transient individuals and an ever-changing collection of fauna). EPA's national standards are based on assumptions that do not resemble offshore conditions and exposures. Under the conditions of the offshore Arctic, using the NAAQS and increment as criteria is overly conservative, misleading, and will necessarily predict "significant" environmental impacts where none will actually occur.

3. Shell's Recommendations

Shell has developed more suitable criteria to govern offshore air quality related to its remote, offshore exploration activities in the Chukchi Sea. These proposed air quality standards for air pollutant concentrations in remote offshore regions of the Arctic Ocean consider the characteristics and activities of the population that accesses the region. The standards are appropriately based on the following assumptions:

- Short-term averaging periods due to transience (1 hour is appropriate).
- The population accessing the Arctic OCS region, particularly those who travel in boats far offshore to hunt, generally comprises persons for whom OSHA standards provide appropriate health protection.¹

Standards for NO₂, PM_{2.5}, PM₁₀, carbon monoxide (CO), and sulfur dioxide (SO₂) were developed by Shell based upon these assumptions, scientific evidence, and OSHA standards. Given these conditions, conservative standards for the offshore area are provided that are based on current occupational health standards or studies focused on non-medically compromised individuals.

NO₂:

As discussed previously, NAAQS are not an appropriate set of criteria for assessing levels of impact in offshore Arctic areas. However, EPA has provided valuable information under NAAQS assessments that is relevant when evaluating acceptable air quality levels for offshore areas for the Arctic region in the Chukchi Sea. The EPA Integrated Science Assessment (ISA) for NO₂^m provides the basis for the current ambient concentration thresholds established in the NAAQS. The 1-hour NAAQS for NO₂ (100 ppbⁿ) has been established with regard to the most sensitive individuals. Sensitive asthmatics have shown the highest sensitivity to short-term NO₂ exposure with increased airway response to concentrations as low as

¹ Nevertheless, given that some members of the native population may be more susceptible to the health effects of air pollutant exposure due to genetic predisposition, and might conceivably engage in subsistence activities offshore, the standards are more stringent than the OSHA standards to even more fully protect the subsistence worker population.

^m USEPA (2008): Integrated Science Assessment for Oxides of Nitrogen – Health Criteria, EPA/600/R-08/071.

ⁿ 1 part per million (ppm) = 1000 parts per billion (ppb).

100 ppb after 60 minutes of exposure. Increased sensitivity is evident at 200-300 ppb for shorter, 30 minute periods of exposure. Minimal airway response has been observed in healthy non-smoker non-asthmatics at levels as low as 1.5-2 ppm after continuous 1-hour exposure. Intermittent exposure to 2 ppm NO₂ concentrations evoked no airway response in these individuals.

The ISA also directs attention to NO₂ exposure by laboratory animals that demonstrate increased airway responsiveness after 6-12 weeks of exposure to a concentration of NO₂ at 1-4 ppm. This suggests that animals are sensitive to NO₂ at a similar concentration range as humans. Therefore, it is appropriate that the primary and secondary criteria level for NO₂ be roughly equivalent. Secondary criteria for NO₂ are also relevant to the protection of coastal regions from nitrogen deposition that may contribute to a disturbance of the biological balance by encouraging algal growth.^o Deposition is primarily a concern in onshore coastal regions where build-up of nitrates in coastal estuaries may disrupt biological balances.^p

OSHA has established air quality limits for a range of pollutants to protect the health of laborers in the workplace. Though the established levels are less stringent than the NAAQS, the standards have been recognized as conservative levels of protection for the average healthy worker in the United States. The OSHA standard for NO₂ is defined in Table Z-1 of OSHA Standard 1910.1000 (29 CFR 1910.1). Under the OSHA standard, NO₂ must not exceed 5 ppm at any time.

Given the scientific research and OSHA standards presented here, an NO₂ criteria concentration level in the range of 2 to 5 ppm (3760-9400 µg/m³) over a 1-hour average period is a reasonable and conservative level of health protection for that population that may be exposed to pollutants in the offshore regions of the Chukchi Sea.

PM_{2.5} and PM₁₀:

The 2009 EPA Integrated Science Assessment for Particulate Matter^q indicates health effects are generally more related to long-term exposure and the NAAQS values are based on distribution of deaths and hospitalizations with relation to PM_{2.5} concentration. The EPA notes in the 2011 Particulate Matter Policy Statement^r that “protection from long term and short term PM_{2.5} exposure is most effectively and efficiently provided by relying primarily on the annual standard, with the 24-hour standard providing supplemental protection for days with high peak concentration.” This statement demonstrates the EPA’s interpretation of the ISA findings that PM_{2.5} exposure is generally a concern for longer (>1 hour) exposures.

The OSHA standard for respirable fraction (PM₁₀) of suspended particulates, otherwise not regulated under another standard, is 5,000 µg/m³, averaged over an 8-hour workday. This value is considerably higher than the 24-hour NAAQS of 150 µg/m³ for PM₁₀ or 35 µg/m³ for PM_{2.5}. The most stringent OSHA standard for any respirable dust material is 500 µg/m³ for Paraquat, a highly toxic compound.

The current NAAQS include standards for both PM₁₀ and PM_{2.5}. PM_{2.5} is of greater concern because particles in this size range stay airborne longer, can penetrate deeper into the lungs, and are generally comprised of the more toxic compounds. When determining criteria, it is highly conservative to set the same concentration threshold value for both PM₁₀ and PM_{2.5}, given an appropriate health-based limit for PM_{2.5} exposure. This approach effectively assumes that all PM₁₀ is PM_{2.5} for the sake of environmental assessment. The 24-hour average concentration NAAQS for PM_{2.5} is roughly a quarter of the PM₁₀

^o USEPA (2008): Integrated Science Assessment for Oxides of Nitrogen and Sulfur -- Ecological Criteria, EPA/600/R08/O82F.

^p Id.

^q USEPA (2009): Integrated Science Assessment for Particulate Matter, EPA/600/R-08/139F.

^r USEPA (2011): Policy Assessment for the Review of the Particulate Matter National Ambient Air Quality Standards, EPA-452/R-11-003.

NAAQS concentration; it is therefore more conservative to apply a health-based criteria threshold for $PM_{2.5}$ that is less than a quarter of the OSHA respirable fraction limit (PM_{10}).

Given the scientific research and OSHA standards presented here, $PM_{2.5}$ and PM_{10} criteria concentration threshold of $500 \mu\text{g}/\text{m}^3$ over a 1-hour average period would provide a reasonable and highly conservative level of health protection (considering that the OSHA standard of $5,000 \mu\text{g}/\text{m}^3$ is based on *8-hour average* concentrations) for the population who might be exposed to pollutants in the offshore regions of the Chukchi Sea.

In terms of impacts on the environment, the primary concern being the health of marine life exposed to $PM_{2.5}$ in the offshore regions, there is limited information concerning the impacts of deposited or airborne PM .^r The body of scientific studies focused on health impacts of $PM_{2.5}$ on animals is sparse, but effects are expected to be at the same concentrations as humans thus, the criteria for humans should be appropriate for protection of marine life.

CO:

The NAAQS for CO are based on clinical evidence that relate carboxyhemoglobin (COHb) to a number of health impacts. COHb is formed from the bonding of CO and hemoglobin in the blood that hinders the transport and delivery of oxygen throughout the body. The CO NAAQS were set to protect the health of those most vulnerable to the effects of COHb, which include those susceptible to exercise-induced angina, asthma, coronary artery disease, and myocardial ischemia. The developing young and elderly are also more sensitive to CO exposure. It has been noted that persons with normal healthy cardiovascular systems can tolerate “substantial concentrations of CO” if they increase cardiovascular output in response to higher COHb. Individuals with compromised systems have limited ability to respond to higher COHb, making them susceptible to even low concentrations of CO.^s

The OSHA 8-hour exposure limit for CO is $55,000 \mu\text{g}/\text{m}^3$ (50 ppm) (8-hour average). It has been found that a 1-hour exposure of up to 1,200 ppm would cause unpleasant but no dangerous symptoms.^t The OSHA exposure limit is a reasonable primary and secondary threshold for workers and those engaged in subsistence activities in the Chukchi Sea. A conservative criteria level, based on the OSHA standard, would be 1-hour average threshold of 50 ppm.

SO₂:

Short-term SO_2 NAAQS have been established to protect the most susceptible individuals, which include severe asthmatics and those with pre-existing respiratory disease such as Chronic Obstructive Pulmonary Disease. SO_2 -related health impacts in healthy individuals have not been demonstrated at concentrations $< 1,000 \text{ ppb}$.^{u,v} Increase in respiratory symptoms have been observed in exercising asthmatics following 5 to 10 minute exposure to SO_2 levels as low as 200-300 ppb. Given these observations, the 1-hour SO_2 NAAQS has been set at 250 ppb (not to be exceeded more than twice per year) to limit health impacts on the most susceptible individuals.

The OSHA permissible exposure limit is 5 ppm ($13 \text{ mg}/\text{m}^3$) (8-hour exposure). The California OSHA standard is lower, however, at 2 ppm. Shell has adopted a more protective and conservative value (given

^s USEPA (2010): Quantitative Risk and Exposure Assessment for Carbon Monoxide – Amended, EPA-452/R-10-009.

^t Center for Disease Control, IDLHs for Carbon Monoxide: <http://www.cdc.gov/niosh/idlh/630080.html>.

^u USEPA (2009): Risk and Exposure Assessment to Support the Review of the SO_2 Primary National Ambient Air Quality Standards, EPA-452/R-09-007.

^v Sulfur dioxide final acute exposure guideline levels (May, 2008).

the temporal averaging period of the standard) of 2 ppm^w (1-hour average concentration) to provide adequate protection of workers and subsistence hunters and fishermen on the Chukchi Sea.

The secondary NAAQS are established primarily to protect against the acidification of the environment from SO₂ pollution. Build-up of SO₂ in the air can lead to acid rain and deposition can increase the acidity of isolated marine environments, where pollutants can concentrate. These factors are not an issue over the offshore regions of the Arctic Ocean due to the lack of widespread SO₂ sources. Acidification is primarily a concern in coastal areas due to the buildup of sulfur in estuaries and marshlands: similar buildup is impossible over the open ocean, where any deposited sulfur will disperse quickly. Impacts on marine life should be averted by adherence to health-based limits set for human exposure.

^w 2 ppm = 2,000 ppb.