Memorandum

To: *Chicago Department of Public Health*

From: *Edmund Crouch, Ph.D.*

Date: *December 5, 2014*

Subject: *Variation of particulate emissions with pile height*

In its variance request (KCBX, 2014), KCBX states "Because of KCBX's existing dust suppression techniques, pile heights up to 45 feet would not result in an increased threat of fugitive emissions and would not create a public nuisance or adversely impact the surrounding area, surrounding environment, or surrounding property uses." In support of its variance request, KCBX provided the City of Chicago with a letter from Sonoma Technology, Inc. (Sonoma, 2014) that states "lowering pile heights from 45 ft to 30 ft while keeping other modeling inputs constant has a small influence on the modeled air quality impacts from the KCBX Terminals, and results in a slight increase to those impacts." Sonoma Technology, Inc., came to this conclusion by modifying the emission height of estimated fugitive emissions from the piles, but leaving the size of the emissions constant.

Without going into the precise methodology used by Sonoma Technology, Inc., the relevant caveat in this statement is "while keeping other modeling inputs constant." There was no documented attempt to evaluate whether those other modeling inputs, in particular the relevant wind speeds, more generally the wind field, and the consequent emission rates, would be affected by changes in the heights of the piles. However, changing the pile heights will change the wind field, relevant wind speeds, and consequently the emission rates.

First, changing the pile heights will change the heights at which various equipment operates. In particular, the drop points of stackers will be at higher elevation in order to drop to the elevated piles. Such drops are clearly envisioned in the FESOP (KCBX, 2012, at Table 1, KM00000427). It is also possible that the drop points of the portable conveyors will be elevated because of the increased pile heights, depending on the configuration of these conveyors. Emission rates from such drops clearly increase with increased wind speed (AP-42, Section 13.2.4-3, http://www.epa.gov/ttn/chief/ap42/ch13/final/c13s0204.pdf), so both the increased height and any change in wind speed with height have to be taken into account. In addition, it appears that KCBX operates equipment (*e.g.*, bulldozers) on top of the piles (see, for example, http://abc7chicago.com/news/petcoke-storage-facility-requests-more-time-to-meet-citys-regulations/313218/ at 1:33 and 1:43 showing vehicle tracks on top of the piles), although such operations do not appear to be listed in the FESOP (*op cit.*) tables of emission points. The emission height of such emissions will be increased by the increased pile height, resulting in a change in

dispersion characteristics and a change in downwind concentrations. Although the predictive emission rate equations for such operations do not depend on wind speed (AP-42, Section 13.2.2-2, http://www.epa.gov/ttn/chief/ap42/ch13/final/c13s0202.pdf), the wind speed will be higher, again changing downwind concentrations as pile height is increased. Moreover, operation of material-moving equipment on piles will effectively expose newly erodible material, leading to an indirect increase in fugitive emissions due to the increased wind speed (as discussed in the following paragraphs) at increased pile height, even if the amount of material-moving remains constant.

Second, wind erosion emissions from the pile itself will also vary as the pile height is varied. Sonoma Technology, Inc. does not state what methodology was used to model emissions from piles, or why these emissions were assumed to be independent of the pile height. The FESOP (2012, Table 2, Footnote 7, KM00000430) uses a 1989 EPA correlation equation[1] that depends on wind speed only through the fraction of time that unobstructed wind speed at the mean pile height exceeds 12 mph; this fraction therefore increases with pile height because of the increase in wind speed with height. However, this correlation equation has been superseded by the methodology described in AP-42, Section 13.2.5 (http://www.epa.gov/ttn/chief/ap42/ch13/final/c13s0205.pdf; last updated November 2006). This current methodology for estimation of wind erosion from storage piles clearly depends strongly on wind speed, reflecting a better understanding of the underlying processes; but the full methodology is based on a "typical" pile height of 11m and gives no indication of how emissions might vary with pile height.

The wind field, and in particular the wind speed, around storage piles, will vary as the height of the storage pile changes. This is a consequence of the general logarithmic increase in wind speed with height under steady state conditions (Gifford, 1968; AP-42, Section 13.2.5), combined with the effect of modification of the wind field by the increased projection of the pile into the wind. The wind speed over the upper surfaces of the pile will increase as the height increases, leading to an expected increase in wind erosion rate as the pile height is increased. In addition, as the pile height is increased, the total surface area of the pile available for erosion will also increase. Insofar as the erosion potential of the pile surface is limited so that the total amount of material erodible by wind (between surface disturbances) per unit surface area is fixed, the total amount eroded will increase with pile height simply because of the increase in surface area.[2] The increased wind speed will also increase the rate of erosion, both effects leading to increases in downwind concentrations, although there are potentially counterbalancing effects on such concentrations through increased height of emission and dilution by the higher wind speed.

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[1] The FESOP cites an "Air Pollution Engineering Manual and References Section 9.3," but with a URL link to a different document. The cited URL is to WRAP (2006) Section 9, where the methodology, obtained from a 1989 EPA report but dating back to 1983, is given as an "Alternate Methodology" not included in AP-42; the "Primary Methodology" described is that provided in AP-42, Section 13.2.5.

[2] This discussion presumes a fixed base area of the pile(s), which seems the most relevant condition since the total area available for pile storage at the KCBX facility is a limiting factor.

The current AP-42 methodology (AP-42, Section 13.2.5) for estimating emissions due to wind erosion from storage piles is based on measurements of wind-induced erosion rates on flat surfaces, combined with wind-tunnel studies (Billman and Arya, 1985; Billman Stunder and Arya, 1988) to evaluate the wind field around piles of fixed height (scaled height 11m). No direct measurement in a wind tunnel appears to have directly measured the effect of pile height on wind fields (or emission rates), and none of the scientific literature has studied the problem in such a way that would allow immediate extrapolation from published studies to the evaluation of the effect of pile heights on emissions at KCBX . The scientific literature does, however, provide a methodology that would allow such an evaluation.

Badr and Harion (2005) performed computational fluid dynamic (CFD) modeling of wind fields around storage piles that matched the wind-tunnel measurements of Billman and Arya, providing confirmation that the CFD modeling approach matched experimental evidence. Badr and Harion (2007) extended this modeling to other pile shapes and sizes, and incorporated the wind-induced erosion rates given in AP-42 in the modeling to obtain total emission rates from such piles. Turpin and Harion (2009) used the same methodology to examine the effect on emissions of truncating the top of piles (and otherwise modifying their shapes and sizes to maintain a constant volume),[3] and Turpin and Harion (2010) have examined the effects of surrounding buildings on the wind field, and the subsequent effect on emissions. Others have uses similar approaches in estimating emissions, for example in various configurations of piles (Cong *et al*., 2012) and different pile shapes (Toraño *et al*., 2007; Diego *et al.*, 2009). There is thus a methodology available that would allow estimation of the effect of different pile heights and configurations on emissions, and the potential shading effects of multiple piles in a small area.

Two further factors that might have to be taken into account in evaluating the effect of pile height on emission rates are (i) any change in total throughput of the site, if this is affected by the change in pile height, and (ii) any change in management of the piles to maintain the same throughput. Neither was addressed in KBCX's variance request nor Sonoma Technology, Inc.'s letter.

If the throughput of the site is reduced by limitation of pile heights, as claimed by KCBX, then emissions from multiple sources at the site will be reduced with reduced pile heights, thereby reducing emissions. On the other hand, it may be possible to maintain throughput of the site by modification of pile configurations and/or management. The FESOP evaluated a specific configuration of piles, and Sonoma Technology, Inc. also evaluated a (different) specific configuration; but no operational basis for selection of the configuration was provided. Management modifications may require changing the rate at which piles are loaded in and/or out, which changes may affect emissions by changing the rate of production of new, wind-erodible surface, hence implying an increase of emissions; or requiring a change in the rate of movement or amount of traffic on top of the piles, with the same effect of breaking crusts and producing new,

[3] This study might have provided some indication of the effect of pile height. Unfortunately, the stated dimensions in Table 1 of the paper do not match the claimed pile characteristics, so interpretation of the results is problematic. A request to the corresponding author for clarification was not answered.

wind-erodible surface. Both of these effects would need to be taken into account in a complete evaluation of the effect of pile height (but are not in Sonoma Technology, Inc.'s letter).

In summary, CDM Smith evaluated the information provided to the City of Chicago by KCBX in support of its claim that pile heights up to 45 feet would not result in increased emissions or adverse impacts on the surrounding area. CDM Smith's evaluation found that, for multiple reasons, increasing the permitted pile height from 30 feet to 45 feet may result in increased emissions. First, increased pile heights change the height at which equipment operates, resulting in a change in downwind concentrations. Second, emissions from the pile itself will increase as pile height is increased due to an increase in windspeed with height and the increased surface area of higher piles. Finally, changing pile heights may affect the total throughput of the site and/or management of the piles, resulting in corresponding changes in emissions. In a complete evaluation of the effect of pile height on emissions and impacts to the surrounding area, these factors should all be taken into consideration.

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