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August 2, 2013

Washington Dairy Products Commission
Washington Dairy Center
4201 198th St. SW
Lynnwood, WA 98036

Attn: Janet Lester and Celest Piette
RE: Scientific literature review

Dear Washington Dairy Products Commission,

As per your request, I have conducted a non-bias, scientific review of the best available literature assessing the potential for human health effects due to the application of dairy manure during times of burn bans in the Yakima Basin. That review, entitled "*Review: Summary of the Existing Science Regarding Public Health Effects from the Spreading of Dairy Manure, With an Emphasis on Effects in Eastern Washington and the Yakima Basin*" is enclosed.

My overall finding and professional opinion is that based on scientific principles, understanding, and review of available literature, that there is no validity to disallowing manure application during times of burn bans. Furthermore, the literature does not support the conclusion that dairy manure applied at agronomic rates to farm fields is a significant hazard to community health in the Yakima region. With the use of best management practices, any potential concerns with air pollutants from manure application can be actively mitigated to avoid potential transport to neighboring areas.

Please feel free to contact me at any time for follow up, expansion, or question of any of the information or opinion provided.

Respectfully,

Nichole M. Embertson, Ph.D.
Nutrient Management and Air Quality Specialist
Whatcom Conservation District
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Enclosed: "*Review: Summary of the Existing Science Regarding Public Health Effects from the Spreading of Dairy Manure, With an Emphasis on Effects in Eastern Washington and the Yakima Basin*"

cc: Jay Gordon and Dan Wood, Washington State Dairy Federation

Review: Summary of the Existing Science Regarding Public Health Effects from the Spreading of Dairy Manure, With an Emphasis on Effects in Eastern Washington and the Yakima Basin

August 2, 2013

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Purpose and Scope

Community members in Yakima, WA raised concerns over perceived health implications of emissions from application of dairy manure during burn bans in the Yakima Basin. They have requested that spraying or spreading of manure (all livestock species) be disallowed during times of burn bans. It is postulated that the community members believe that there is a link between burn bans, manure application, and community health. The purpose of this review and professional assessment is to examine this postulation and assess its validity.

The scope of this review focuses only on dairy and dairy manure. Additionally, this review only looks at the emissions from the application of dairy manure to crop land, not emissions from the dairy operations themselves (i.e., housing, manure storage, etc.).

Summary Opinion

It is the assessment of this reviewer, based on scientific principles, understanding, and review of available literature, that there is no validity to disallowing manure application during times of burn bans. Furthermore, the literature does not support the conclusion that dairy manure applied at agronomic rates to farm fields is a significant hazard to community health in the Yakima region. With the use of best management practices, any potential concerns with air pollutants from manure application can be actively mitigated to avoid potential transport to neighboring areas.

Overview of Yakima Dairy Manure Application Practices

The dairy industry in the Yakima Basin area of Washington State is composed of primarily large scale (average size is 1,200 milk cows) drylot operations. Manure is handled as a liquid when collected from freestall barns, milking parlors, and/or feed alleys and stored in single or multiple stage lagoon systems. Often times the collected liquid manure is sent through a solid separation process where solids are removed from the liquid stream and stockpiled, composed, or dried. The majority of liquid manure is stored and then used on farm as a fertilizer product for crops. Solid manures are recycled on-farm as stall bedding, exported off farm (the majority, >80%, is exported to other agricultural industries), or applied to farm fields. Following best practices, the majority of manure is applied to fields at agronomic rates using crop appropriate technologies. In the Yakima Basin, the primary crop rotation for dairy fields is a winter triticale/corn silage rotation. Other common crops grown in dairy production are corn, alfalfa, sudan grass (in rotation), and/or timothy hay. The crop type will dictate the manure application schedule and application technology. For the triticale/corn rotation, which comprises the majority of dairy based crop land (>75%), manure is applied via injection (liquid) or incorporation (solids) prior to corn planting, and a drop hose irrigation or drag hose surface application of liquid manure to triticale. For triticale, application is generally conducted once in late Feb/early March and post cutting in April with dilute manure (low concentration) using a low-pressure drop hose system. For corn, a heavy application is conducted just prior to planting in May/April using injection or incorporation and a second application using dilute manure in June. A post-harvest, pre triticale planting application is conducted using no-till liquid application technologies in September/October. Forage crops (excluding alfalfa) are usually applied to after each cutting (Feb/Mar, July, and Sept) throughout the growing season using drop hose irrigation or near-surface application technology. A small percentage (<5%) of other crops and less desirable application technologies such as honey wagons (tanks) and Big Gun sprinklers are used for application, but the land acreage applying these technologies is small (<3%). All dairy operations must apply nutrients (i.e., manure) according to their Dairy Nutrient Management Plan which outlines agronomic guidance and application restrictions. Restrictions include when not to apply (i.e., wind >10 mph, inversions, high temperatures, etc.), what local criteria (i.e., schools, neighbors, wells, etc.) and setbacks need to be taken into consideration when applying, and best methods for reducing nutrient losses via volatilization.

This information on application timing and technology is vital in assessing the potential emissions from land application of manure. Different technologies can vary in volatilization losses by 50% (i.e., Big Gun verses injection), and timing influences the degree to which emissions may occur due to meteorological conditions (i.e., temperature, wind speed, etc.). In general, the technologies, timing, and application restriction guidance followed by the majority of dairy operations in Yakima meet the best management practices guidelines encouraged by University guidance and research for maximum reduction of emissions during application for ammonia, dust and odor (Smith et al., 2009; Webb et al, 2010; Rotz et al., 2011; Brandt et al., 2011).

Burn Bans and Manure Application

Conditions that constitute a burn ban are defined in RCW 70.94.473, but typically a burn ban is put into effect when atmospheric conditions are predicted to cause fine particulates ($PM_{2.5}$) in the atmosphere to exceed a specified value due to decreased mixing and subsequent stagnation of air. Burn bans are instated to protect area residents from the negative health effects of an increase in particulates in the local atmosphere. On assessment of burn bans in Yakima within the previous five years (2008-2013), it is observed that the majority of burn bans occur during the winter months (October-February) when seasonal temperature inversions are common, or during the height of fire season (August) when atmospheric particulates are increased due to wildfires and air stagnation is possible. The Department of Ecology (ECY) lists woodstoves as the number one contributor to burn bans in the winter months, and wildland fires in the summer due to $PM_{2.5}$ production; conclusions which are supported in other, similar regions (Ward and Lange, 2009). Agricultural practices, such as manure application, which does not typically occur outside of the growing season during the winter months, do not directly contribute $PM_{2.5}$ to the atmosphere. Rather emissions from manure and nitrogen-based chemical fertilizers are considered a precursor to $PM_{2.5}$ when ammonia from applied nitrogen volatilizes and comes in contact with available nitrous and sulfuric acid gases that are released into the atmosphere from vehicles and combustion processes (NOx and SOx) to form fine particulates through chemical reaction.

Depending on atmospheric conditions and geographic location, this pathway contributes less than 10% of the total secondary $PM_{2.5}$ production in the atmosphere (Hristiv, 2011).

In Yakima, the amount of ammonia volatilized in the winter from dairy manure application is comparatively very low. This is due to multiple factors. Primarily, manure is not typically applied from November to February to the crops grown in dairy production in Yakima, WA. When manure is applied, ammonia volatilization is variable based on manure type and concentration, application technology (losses range from 5% (injection or incorporation) to 50% (non-incorporated, surface applied) (AWMFH, 1998)), and weather conditions, particularly wind speed and precipitation (Misselbrook et al, 2005). Based on the typical manure application practices in the Yakima basin, the loss rate for ammonia during times of winter burn bans will be very low. Additionally, production of dust and odor will also be low in the winter months based on application technology type (irrigation type) and soil moisture (high) (Brandt et al., 2011). Ammonia volatilization is significantly reduced during cold weather due to a thermal reduction in biological and chemical processes in manure and the soil. Manure application and volatilization potential will increase during the hot summer months and losses will be greater due to converse factors, but burn bans outside of wildfires are not typical due to a lack of determinant meteorological conditions.

Emissions from Manure Application

Dairy manure is composed of a ratio of macro and micro nutrients. The primary ones being organic nitrogen, ammonia nitrogen, phosphorous, potassium, minerals, other organics, and pathogens such as fecal coliform. From an air quality perspective, the primarily concerns are with forms of nitrogen that can volatilize (ammonia), hydrogen sulfide produced during anaerobic storage of liquid manure, dust and bioaerosols from dry manures, and odorant compounds. The emission rate and concentration of each of these compounds is highly variable based on the type of manure (liquid, soil, compost), upstream manure management practices, manure application technology (i.e., fertigation, drop hose pressure, injection, surface application, aeration, etc.), meteorological conditions (i.e., wind speed, ambient temperature, relative humidity, etc.), soil temperature moisture and pH, vegetative surface cover, time of year in crop cycle, and more.

In relation to human health concerns and dairy manure application, the primary emissions we will look at are ammonia, course particulate matter (dust), and odor.

Ammonia and PM2.5. Ammonia is produced from applied manure when conditions such as temperature, pH, and oxygenation allow hydrolysis of urea (in urine) and urease (in feces and soil) to form ammonia gas. For land applied manure, this reaction is catalyzed by the increased surface area and exposure of manure to aerobic conditions on the soil surface. Ammonia volatilization typically peaks within hours to days of application depending on manure type (solid verses liquid), application technology, and meteorological conditions (i.e., wind speed, temperature, precipitation, etc.) (Amon et al., 2006; Hristov et al., 2009; Leytem and Dungan, 2009). Compared to manure, chemical based nitrogen fertilizers, used in almost all other agricultural cropping systems, can have a higher ammonia volatilization potential when not applied properly.

When in gaseous form, ammonia has a relatively short lifespan of a few hours and usually deposits near its source via wet (rain) or dry deposition depending on meteorological conditions. While manure does not directly produce $PM_{2.5}$, while still suspended in the atmosphere, ammonia from manure can react with nitrous and sulfuric acids produced from vehicle and combustion processes (NOx and SOx) to chemically form $PM_{2.5}$.

Dust (PM10). Course particulate matter (PM_{10}), often times referred to as dust, is produced when mechanical action breaks down solid particles into smaller, mobile sizes. Dust is composed of a variety of compounds based on its nature and origin (i.e., soil, manure, etc.). Most course PM will settle out close to its origin depending on factors such as particle size, wind speed and direction, relative humidity, and temperature. The potential for production of airborne course dust from applied manure comes from dry/solid manures, compost, and aerosolized liquids and depends on the moisture content, application method, and particle size. In general, most studies show that the general trend is for a reduction in dust and bioaerosl concentration with distance from the source (Dungan, 2010). Transport of PM_{10} can vary from a distance of 40 feet with liquid manure application with a "Big Gun" sprinkler, while other methods such as a tank spreader failed to have transport up to 10 feet and injection showing no transport at all (Hutchison et al., 2008). Dry manure may transport to greater distances depending on wind speed and manure characteristics such as moisture and particle size. In general, application methods that have a larger droplet size or inject or incorporate manures, will have a low prevalence of creating dust and subsequent airborne bioaerosols (Millner, 2009). Studies have shown that odors, gases, and biological material can be attached to airborne course PM (Cambria-Lopez et al., 2010). However, while biologically derived aerosols (bioaersols), such as fecal and bacterial origin dust, may be present in manure applied to fields, survivability of pathogens through the manure storage period, treatment, and application process is low (McGarvey et al., 2004; Ravva et al., 2006; Grewal et al., 2006). Factors such as decreased relative humidity, increased temperature, and high solar irradiance, common conditions in the Yakima Region, as well as and increased oxygenation greatly reduce the survivability of microorganisms in applied manure (Dungan, 2010). The typical source of dust from agricultural practices comes from housing, grain harvesting, and airborne soil particles from tillage and traffic over dry and/or fallow crop fields rather than manure application (Lee et al., 2006). Dust emanating from these sources is regulated and must be limited via reasonable best management practices.

Odor. Odor is typically referred to as a nuisance pollutant, rather than criteria pollutant, because it is not characterized as a direct threat to public health by EPA and therefore not federally regulated. There is no argument that manure has an odor to it. However, characterization of the odor is very difficult. This is because odor is a highly variable compound composed of sometimes hundreds of individual odorants/compounds. The odor profile and intensity of a manure will vary depending on many factors including animal diet, manure handling practices, manure type, application technology, and ambient conditions (i.e., temperature, relative humidity, etc.). In addition, the offensiveness of and reaction to an odor will significantly differ between individuals making characterization difficult (Schiffman, 1998; Schiffman et al., 2004; Schiffman and Williams, 2005). Therefore, instead of discussing odorants as an individual air pollutant, we tend to talk about the major constituents of odors and address those directly such as ammonia, hydrogen sulfide, or volatile organic compounds (VOC).

Manure Application and Health Effects

All of the pollutants emitted by manure have the potential to effect human health, but the thresholds and concentrations at which those impacts can occur are typically very low away from their source. While there is a large database of studies related to the health effects of agricultural practices on farm workers, very few studies are available on the direct health effects of dairy manure application on surrounding communities. In fact, a comprehensive review of scientific studies conducted by O'Conner et al. (2010) looked at the associations between animal feeding operations and measures of health of individuals living near animal feeding operations and found that there were very few applicable studies (0.2%) and no compelling evidence for a consistent, strong association between the clinical measures of disease and proximity to animal feeding operations. Additionally, the majority of studies conducted look at the emissions from the operational and housing facilities, not land application. The lack of relevant studies stems from the difficulty of conducting a scientifically relevant health related study that looks at multiple facilities and community areas, is long term, and is statistically relevant and replicable. Additionally, a study surveying quality of life characteristic of residents living near and far from animal feeding operations concluded that emotional considerations, not physiological ones, played a large part in perception of the impact of those facilities on health (Schmalzried and Fallon, 2007). Of the few relevant studies available, most are largely inconclusive and/or found no direct, replicable connection between farm exposure and health effects (Merchant et al., 2004; Heederik et al., 2007; Murayama et al., 2010). In fact, a study examining the exposure of residents in the Yakima Valley to airborne cow allergen, ammonia and PM found concentrations magnitudes below the Occupational Safety and Health Administration (OSHA) and National Institute for Occupational Safety and Health (NIOSH) standards for exposure limits (Williams et al., 2011). In some cases, children born on farms with constant exposure have lower incidences of diagnosed allergies than non-farm raise children (Merchant et al., 2004).

Pollutant Exposure Limits

In order to protect people from the detrimental effects of pollutants, the Occupational Safety and Health Administration (OSHA) and the National Institute for Occupational Safety and Health (NIOSH) have created exposure limits for different categories of people. Of the pollutants of concern with land application of manure, only ammonia and course dust have exposure limits. Odor does not have an exposure limit because it is compiled of a variety of different compounds, each with its individual exposure limits when applicable.

Ammonia. Due to the side effects of ammonia exposure, the American Conference of Governmental Industrial Hygienists (ACGIH) and National Institute for Occupational Safety and Health (NIOSH) has recommended an 8 hour maximum exposure limit of 25 ppm to protect against the chronic effects of ammonia exposure for those working in close proximity, such as on-farm workers. A 15 min short term exposure limit of 35 ppm has been established by ACGIH and also adopted by OSHA to reduce irritant effects of ammonia exposure (i.e. eye and upper respiratory tract irritation). Due to possible cumulative health effects over time, the recommended daily long term occupational exposure limit of ammonia for agricultural workers is 7 ppm (Donham et al., 2000) , and 300 parts per billion (ppb) for community exposure (this accounts for sensitivity in the elderly and infants) (Merchant et al., 2003).Downwind measures of ammonia from applied manure rarely exceed concentrations in parts per billion (ppb) (Williams et al., 2011) and will vary greatly based on application practices, as has been discussed.

Dust (PM10). The health concern over dust is from direct respiration. Permissible 8-hour exposure limits to total dust is 15 mg/m^3 (CAL/OSHA). No threshold limits have been set for bioaerosols in manure. If present in manure, bioaerosols have the potential to be transported from land applied liquid and dry manures. The transport distance will vary depending on wind speed, wind direction, relative humidity, temperature, manure application equipment type, and manure type (Dungan, 2010; Dungan and Leytem, 2011). Typically, the number of pathogens in the manure decreases with storage length or treatment, or are killed upon exposure to temperature, sunlight and/or oxygen at application (McGarvey et al., 2004; Ravva et al., 2006; Grewal et al., 2006; Hutchison et al., 2008; Dungan, 2010), thus limiting the potential for transport during manure application.

Odor. The emission that has the strongest self-reported dose response is to odor; yet clinical measures showed no consistent association between odor concentration and reported symptoms (O'Conner et al., 2010), and no exposure limits are imposed for general odor (some individual odorants do have exposure limits). This is characteristic of psychophysiological response to odorants (i.e., the odorant compounds stimulate receptors in the nasal cavity which ultimately lead to the brain registering the response and producing a physiological response based on physiological determination). Studies have shown that the brain can produce a variety of various responses to odors based on the sensation/perception of the odor, and the chemical nature of the odorant (Schiffman et al., 2004), which makes addressing odor complaints very difficult. Common symptoms and complaints from exposure to odorants range broadly from watery eyes, throat irritation, headache, to nausea (Schiffman, 1998). The response rate by an individual will vary greatly based on previous exposure, learned behavior/association, perception of the effect of odorant (adaptation (reduction in response rate over time) verses sensitization (increase in response rate over time)), and general well-being (Schiffman, 1998; Schiffman et al., 2004; Schiffman and Williams, 2005). In many cases, individuals will report adverse effects of odorants well below the levels that cause irritation or toxicological symptoms (Schiffman and Williams, 2005).

Conclusion

Limited data is available on the direct effects of land application of dairy manure on public (not worker) health, but data extrapolated from studies looking at emission rates of ammonia, dust (including bioaerosol), and odor from land application methods, OSHA/NIOSH exposure limit thresholds, and dairy manure application practices in Yakima, concludes that there is likely no significant benefit to public health from exclusion of land application of dairy manure in the Yakima Region, particularly during burn bans. Of the emissions from land applied dairy manure that have the potential to effect local atmospheric conditions and communities, only ammonia is of significance due to its potential to react with nitrous and sulfuric acids in the atmosphere to chemically form $PM_{2.5}$. Of lesser significance is course particulate matter and odor which tend to be either low due to the moisture content and application methods of manure or not a substantiated threat to human health in the Yakima Region, respectively. It is recommended that the use of best available land application practices continue to be employed with land applying dairy manure in the Yakima Region to reduce any excess emissions.

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