A Tool Box for Assessing Cow, Udder and Teat Hygiene

Paper presented at the 2007 annual meeting of the NMC, by
Nigel B. Cook and Douglas J. Reinemann
University of Wisconsin-Madison

Introduction

Infection of the mammary gland with environmental bacterial pathogens is the most significant udder health problem facing the dairy industry in North America. Forty years ago, Neave et al. (1966) stated that the rate of new intra-mammary infection is related to the number of bacteria that the teat end is exposed to, and several studies have made associations between clean housing, clean cows and lower bulk tank somatic cell counts (Bodoh et al., 1976; Barkema et al., 1998; Barkema et al., 1999). In addition, Bartlett et al. (1992) found that an index of environmental sanitation based on the amount of manure on the cow and in her environment was a predictor of the occurrence of coliform mastitis, and Ward et al. (2002) noted that in four study herds, the lowest incidence of mastitis occurred in the herd with the cleanest cows and the most satisfactory beds.

Despite the improvements made in so many other areas of the dairy industry, our ability to keep cows clean and to reduce the bacterial load at the teat end has improved little. Increases in herd size, poor stall design, infrequent alley scraping and manure removal, pressure for milkers to increase parlor throughput, and changes in the availability and use of different bedding materials have all worked against significant progress in this area. Moreover, our inability to accurately document the effects of these failures has allowed detrimental changes in management to be amplified.

The clinician presented with an environmental mastitis problem must have a tool box at his/her disposal that serves to communicate the problem of environmental contamination to the herd owner, so that interventions can be made and improvements documented. This paper serves to track environmental contamination from its sources (manure and bedding), through contamination of the teat end and failure to adequately clean the teat, to contamination of the milk and infection of the mammary gland.

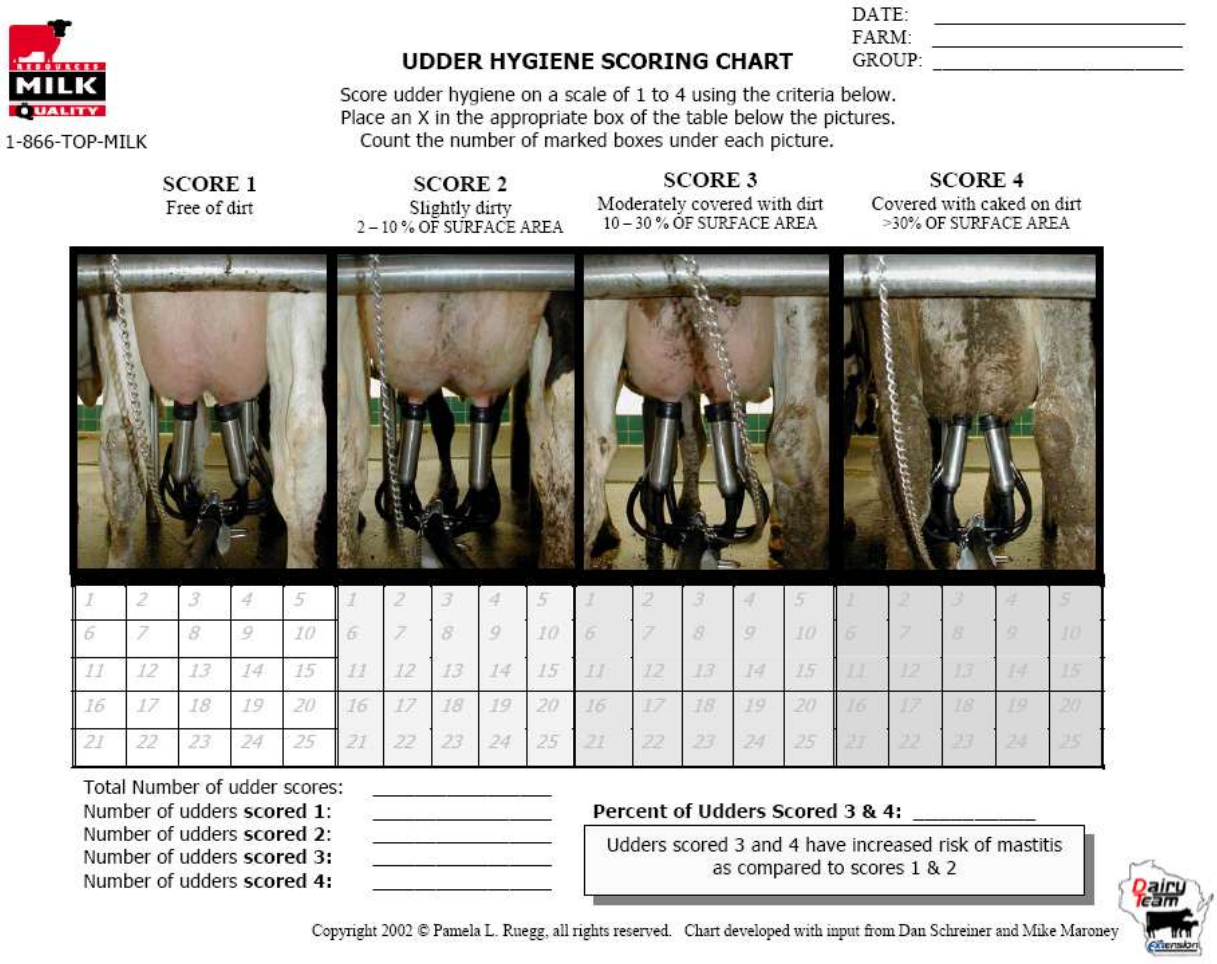
The predominant sources of coliforms and environmental streptococci (*S.uberis, S.dysgalactiae, Enerococcus spp.*) are manure and bedding materials. The cleaner we can keep the cows and the lower the bacterial count of the bedding, the fewer problems we will see. The tools we have to assess the degree of contamination in the environment are hygiene scores of the cows, culture of the bedding and assessment of teat end contamination.

Tools to Assess Udder Contamination

Several different methods of hygiene scoring have been documented (Cook, 2002; Schreiner and Ruegg, 2003; Reneau et al., 2005) and some have been used to prove that poor hygiene results in udder health problems. Schreiner and Ruegg (2003) used the udder hygiene scoring system in Figure 1 to document the degree of contamination of 1250 cows in 8 herds. Udder hygiene scores averaged 22% score 3 and 4 and a significant association between poor udder hygiene and

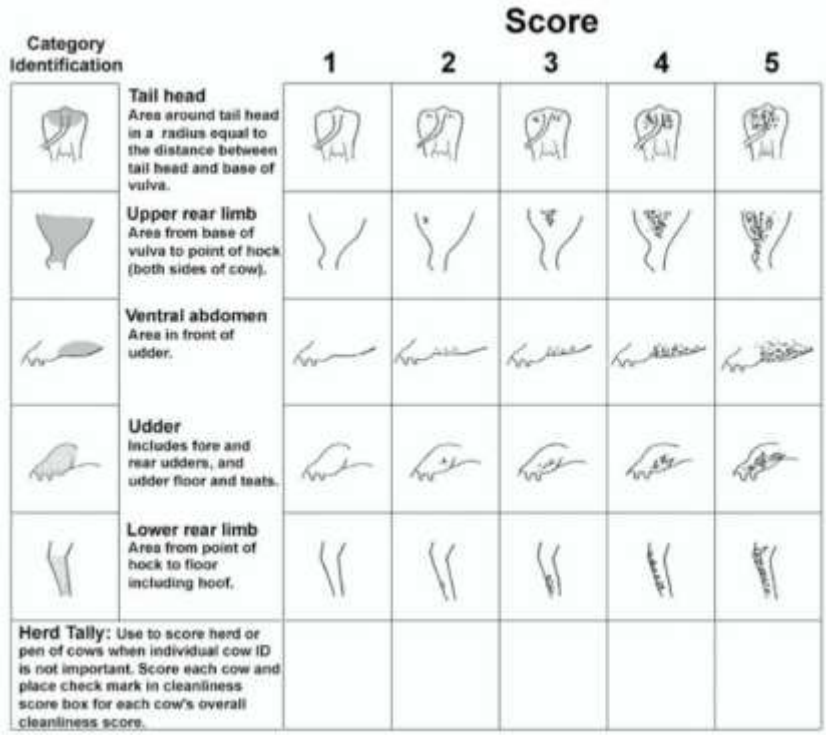
increasing individual cow linear score and the prevalence of intramammary infection with an environmental pathogen was reported. In fact, cows with udder scores of 3 and 4 were 1.5 times more likely to be infected with a major pathogen than cows with scores of 1 or 2. The study reported only a weak association between leg hygiene score and the prevalence of pathogen isolation from the udder.

Figure 1. Udder hygiene scoring chart available from UW Extension. The chart is available at: http://www.uwex.edu/milkquality/PDF/UDDER%20HYGIENE%20CHART.pdf



Reneau et al. (2005) used the more complex scoring system in Figure 2 to document hygiene in 1,093 cows in 8 herds and showed a significant association between udder and lower leg hygiene and individual cow linear score measured within 2 days of recording.

Figure 2. Hygiene scoring system used by Reneau et al., (2005) which serves to document the degree of manure contamination in 5 different areas using a 5 point scale.

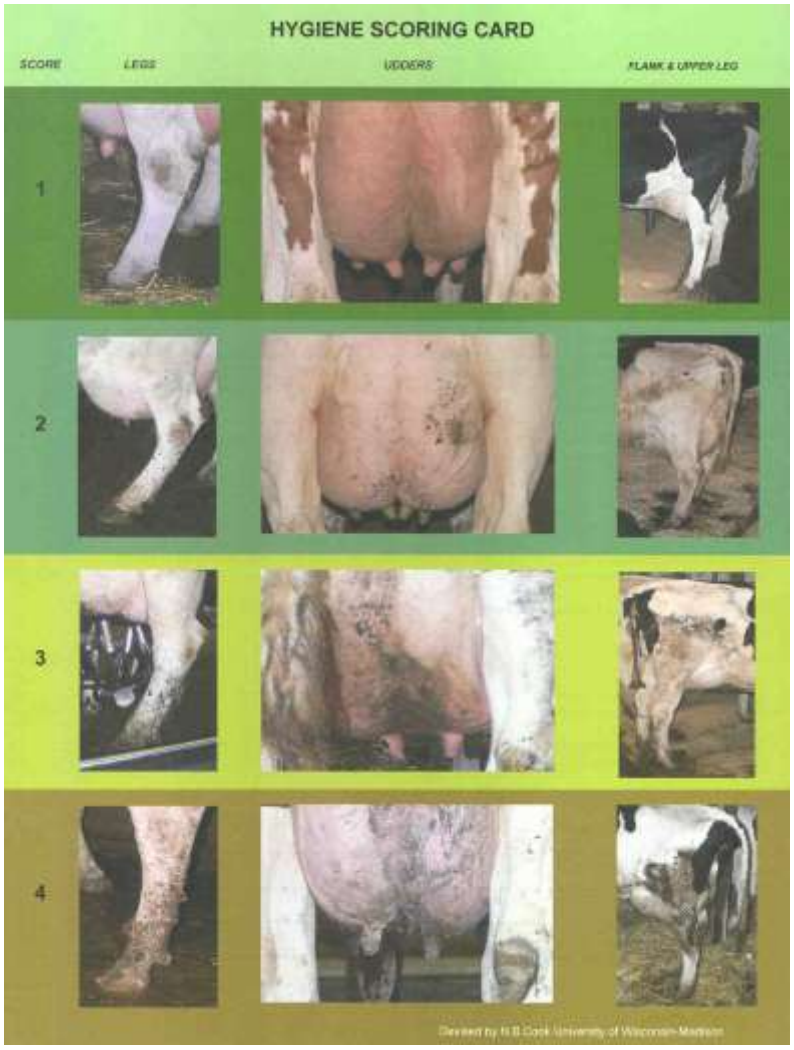


While these hygiene scoring tools have been useful for research and documentation of the degree of udder contamination, they do not communicate the reasons for manure contamination of the udder very well. There are four basic manure transfer mechanisms to the udder, and the relative importance of each differs with the type of housing under consideration:

1. **Direct Transfer**. Cows may lie down in a manure contaminated stall or bedded area (or sometimes in a traffic alley!) and transfer bacteria directly to the udder.
2. **Leg Transfer**. Cows may walk through manure, coating their feet and legs, which transfers bacteria to the teat ends when the cow lies down and the udder comes to rest on one of the hind feet (Abe, 1999).
3. **Splash Transfer**. Cows walking though deep liquid slurry will splash manure up toward the udder.
4. **Tail Transfer**. In some situations, the tail may become heavily contaminated with manure and transfer bacteria to the rear udder and flank areas (Abe, 1999).

The pattern of manure contamination and the mechanism of transfer therefore becomes a very important concept to communicate to the herd owner. With this knowledge, the most appropriate intervention can be recommended and for that reason, the author uses a simplified multi-zone hygiene scoring system (Figure 3), scoring the udder, lower legs and upper leg and flank zones of cows on a 1-4 scale. For reasons of communication, the proportion of scores that are 3 and 4 are presented, rather than a mean hygiene score. During investigations, we typically score 20% of the cows in each pen, or all of the cows in small herds.

Figure 3. A hygiene scoring card which documents the degree of manure contamination on a 1-4 scale for each of three zones, the udder, the lower leg and the upper leg and flank. The score sheet is available at http://www.vetmed.wisc.edu/dms/fapm/fapmtools/4hygiene/hygiene.pdf



The hygiene scoring data from 58 farms collected by the SVM food animal production medicine group suggests that on average, 19% of udders are score 3 and 4 and have an elevated risk of infection. While tie stall cows generally have cleaner lower limbs and less leg transfer, direct transfer is the predominant means of manure contamination of the udder – from manure deposited on the stall surface. Upper leg and flank scores are usually much poorer than in free stalls, reflecting the risk associated with spending around 22 hours per day in a tie stall.

In contrast, the lower legs of free stall cows are far more contaminated than tie stall cows and leg transfer is a significant risk for udder contamination. Splash transfer in poorly draining alleys is also significant.

Table 1. Median and upper quartile proportion of hygiene scores 3 and 4 for each zone for cows in 58 Wisconsin dairy herds by housing type (46 Free stall and 12 Tie stall).

Housing Type	Proportion Hygiene Scores 3 and 4 (%)					
	Udder		Lower Leg		Upper Leg and Flank	
	Median	Top 25%	Median	Top 25%	Median	Top 25%
Free stall n=46	19	11	59	47	15	8
Tie stall n=12	19	10	22	15	27	17

There are many factors involved in creating the pattern of manure contamination observed in cows on our dairy farms and these have been discussed in more detail elsewhere (Cook, 2004). A very common finding however, is for cows in sand bedded herds to be cleaner than in mattress herds bedded with sawdust (Table 3). This finding may be due to the cleaning effect of sand, differences in cow behavior in barns with the two different types of bedding surface, and less slipping and splash transfer in sand bedded herds.

Table 3. Least squares mean (SE) hygiene scores (Proportion scoring 3 and 4 for each zone) obtained independently by two observers from a minimum of 20 cows in the high group pen on 12 free stall herds (6 sand and 6 mattress) compared using 1-way ANOVA.

Zone	Proportion Hygiene Scores 3 and 4 (%)		SE	P Value
	Sand	Mattress		
Udder	16.7	33.3	4.2	0.02
Lower Leg	39.2	74.2	8.6	0.02
Upper Leg and Flank	1.7	11.7	2.1	0.01

a. Tools to Assess Bedding Contamination

In recent years, with the commercial availability of a service to perform bedding cultures at the Udder Health Laboratory at the University of Minnesota, it has become routine to determine bacterial contamination of the bedding. We typically compare fresh bedding material with that sampled from beds after several days of use. We use a gallon ziplock bag to gather handfuls of

bedding from the rear of 10-15 stalls in each pen. The sample is mixed and sub-sampled into a quart ziplock and frozen until the sample is sent on ice to the laboratory for analysis.

Recommendations from the literature suggest that the total count of bacteria in used bedding must not exceed 1 million CFU/ml. However, while this threshold appears to be valid for organic bedding materials, considerable experience from clinical investigations suggests that this recommendation is flawed in the case of sand bedding.

Table 4 shows the median and upper and lower quartile bedding counts for coliforms and streptococci for 82 sand bedding samples collected from 23 farms. These counts would suggest that coliform mastitis would not be a risk, but streptococcal infection would be a major problem. In fact, in these 23 herds, the proportion of mastitis due to gram negative pathogens averaged 75%, and mastitis due to streptococci was rarely a major problem.

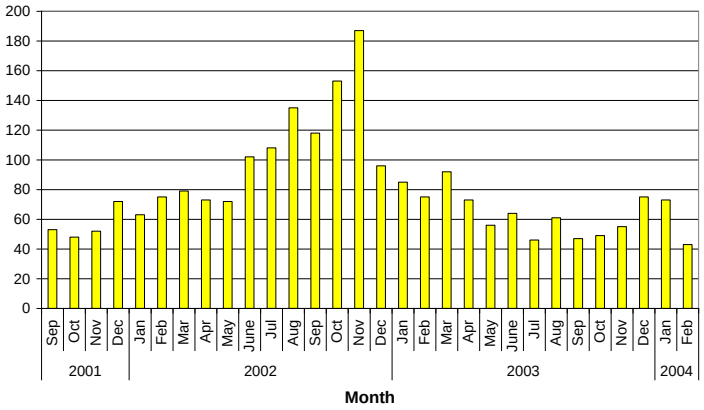
Table 4. Coliform and streptococci counts (CFU/ml) for 82 used sand bedding samples from 23 herds.

Used Sand Bedding Samples	**Count CFU/ml**	
	Coliform Count	**Streptococci Count**
Median	50,000	6,650,000
Upper Quartile	10,000	2,612,500
Lower Quartile	134,250	14,787,500

Thresholds used by the author differ from published data. We have found significant gram negative mastitis problems (*Klebsiella spp* in particular) at a coliform threshold of 100,000/ml, and this is typically used as our intervention level. Even lower counts have been used in very cold weather during the winter. Streptococcal counts in sand can rarely be kept below 1 million /ml, and high counts usually reflect the duration of sand retention in the beds – ie. we can keep the count lower by increasing the turnover rate of the material.

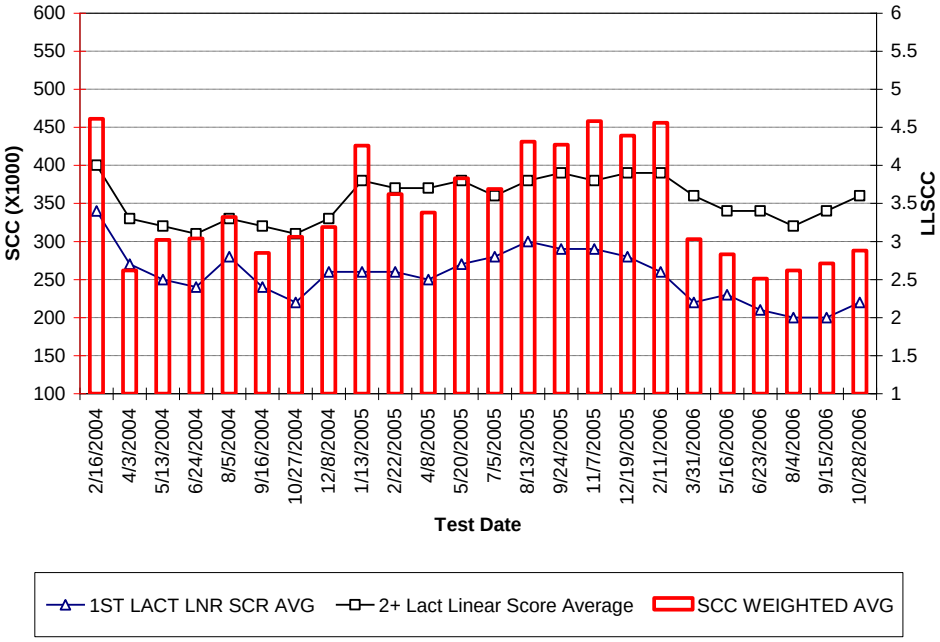
We have successfully improved the rate of clinical mastitis and lowered herd BTSCC by removing contaminated sand bedding and changing to coarser screened sand rather than fine sand (Cook, 2006). The 1314 cow dairy shown in Figure 4 was suffering an extremely high gram negative clinical case rate in the summer of 2002. Following sand removal and replacement, the case rate was halved in 2 months and returned to target levels within 6 months.

Figure 4. Quarter cases of clinical mastitis by month before and after sand removal from the free stalls in a 1314 cow dairy in November 2002.



More recently, a 1400 cow dairy was visited in February 2006 with contaminated compacted sand stalls. The sand was removed and replaced with a coarse washed mason sand. Not only did cow comfort improve, but clinical treatment rate and bulk tank SCC was halved within one month (Figure 5). In these herds, we now keep the coliform counts in the bedding less than 10,000/ml and see many fewer gram negative clinical cases.

Figure 5. SCC response at a 1400 cow dairy where sand was removed from stalls in February 2006 and the fine sand replaced with coarse washed mason sand.



Correlations between bedding counts and teat end contamination have been made (Zdanowicz et al., 2004) and confirm that higher correlations are generally made for organic bedding than for

sand. In particular, the correlation between streptococcal sand bedding counts and teat end counts is low (r=0.28, P=0.06), compared with that for *Klebsiella spp* (r=0.40, P<0.05). More research is needed to fully understand the transfer mechanisms of pathogen groups from the bedding to the udder, but in the mean time, these anecdotal reports confirm that dramatic improvements in udder health can be achieved by lowering the teat end challenge from contaminated bedding, and bedding culture has a role to play in quantifying this challenge.

Tools to Assess Teat Contamination

Teat end sanitation is important in reducing the number of bacteria at the teat end before the milking unit is attached, thus reducing transfer of organisms from cow to cow by the milking machine. Proper teat end disinfection can reduce teat surface bacteria by 75% (Ruegg et al., 2000; Galton et al., 1984; Galton et al., 1986). Pre-dipping with a sanitizer was associated with reduced pathogen content in milk (Hassan et al., 1999) and has been shown to be effective in the control of environmental pathogens (Pankey, et al, 1987; Ruegg and Dohoo, 1997). While cleaning teats with water and wiping dry reduces the number of microorganisms on the teat skin, the reduction is significantly higher when teats are disinfected (Brito et al., 2000). Contact time of 20-30 seconds is needed for effective disinfection for most sanitizers.

If washing is required to remove excess manure, the following methods have been demonstrated to significantly reduce pathogen numbers: 1) only teats should be washed, 2) minimal water should be used, 3) teats should be thoroughly dried (Rasmussen, 2000). The most important portion of the teat disinfection process is thorough drying of teat ends. Air-drying is not a satisfactory substitute for manual drying with an individual cloth or paper towel. Water on teats aids in transporting bacteria and concentrating them at the opening of the teat canal. Cloth towels were more effective than paper at removing pathogens in a study by Rasmussen et al., (1991). When cloth towels are used they should be disinfected by washing with bleach or very hot water and drying at high temperature in an automatic dryer (Fox, 1997).

The tools we have available to determine the degree of teat end contamination are culture of the bulk tank and string samples from sub-groups within the herd, and direct swabbing and culture of the teat ends.

Culture of Bulk Milk and String Samples

Bulk tank cultures are routinely submitted from many farms in North America. While they are predominantly used to monitor for the presence of 'contagious' pathogens (*Mycoplasma, S.aureus and S.agalactiae*), counts of coliforms and environmental streptococci (non-agalactiae streps) are also made.

Unfortunately, high levels of environmental bacteria in the bulk tank are difficult to interpret and frequently the wrong conclusions are made. In simple terms, coliforms and streptococci may enter the bulk tank from three sources – udder infections from the cows, teat contamination from manure and bedding, and from the milking machine itself if a biofilm exists. High coliform counts do not automatically mean that the milkers are not cleaning teats adequately!

Often, culture of sub-populations within the herd, such as cows with the last 3 SCC tests >200,000/ml, can enlighten the interpretation of bulk tank culture, as it is not uncommon to see environmental pathogens from the bulk tank (such as *Klebsiella spp* and *S.dysgalactiae*) represented in a high proportion of chronically infected cows which shed large numbers of bacteria.

Sand bedded herds typically suffer very high levels of streptococci in the bulk tank. Bedding counts can be extremely high and if sand particles are not removed from the teat end adequately, then large numbers of streptococci can appear in the bulk milk. Often, adding an extra wipe to the procedure in sand bedded herds can dramatically reduce the streptococci count in the bulk tank milk.

Despite the difficulties in interpretation, samples of bulk tank milk or sub-samples of milk from groups within the herd can be used to help monitor hygiene in the following ways:

1. A base line 'low level' of coliforms and streptococci must first be identified for the herd or group being milked to answer the question – 'what is the lowest achievable level based on milking procedures?'
2. Deviations from the base-line can be tracked over time for milker shifts in order to determine departures from the normal using string samples
3. If significant departures occur, the cow must be ruled out as a source using individual cow culture, and the adequacy of teat preparation must be determined by visual examination.

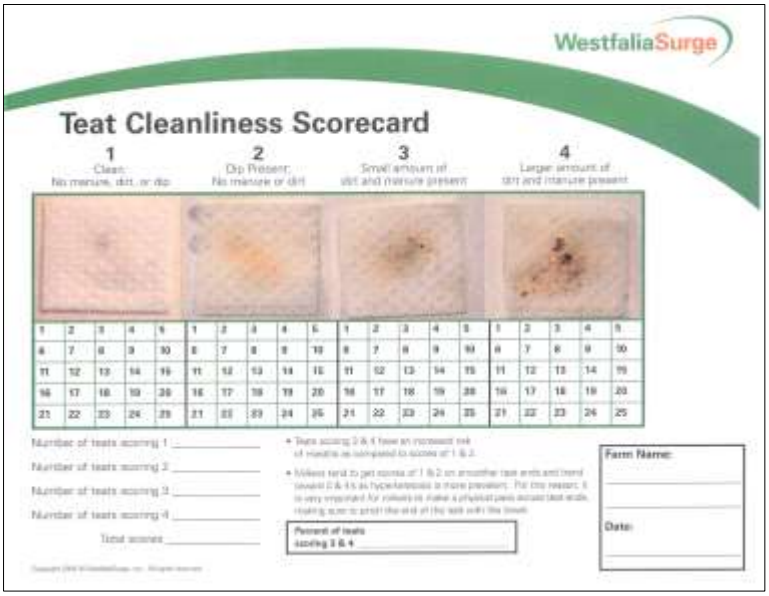
Provided that these guidelines are followed, herds may use culture of the bulk milk or of string samples to determine the adequacy of teat cleaning by the milkers.

Visual Assessments of Contamination

Filter Socks can be visually assessed at the end of each milking or 'string' as an estimate of the relative contamination of teats at the time the milking units are attached. It is also possible to culture these filters to determine the major types and relative magnitudes of bacteria present on teats and in udders at milking time.

To check the effectiveness of teat sanitation and drying, teat end swabs can be taken. A clean swab can be rubbed across the end of the teat prior to unit attachment. A swab from a properly prepared teat will remain clean, while a dirty swab indicates that teat preparation methods should be improved (Figure 6). This technique may be of use on a small number of individual cows, but unlike hygiene scoring, which cannot be easily influenced on the day of capture, it is very easy for milkers to modify their teat preparation procedure to improve teat cleanliness scores over the duration of data capture. As such, benchmarks for the proportion of teats that are too dirty have not been developed and the test remains something that can only be used to demonstrate effective teat prep on an individual cow basis.

Figure 6. Teat Cleanliness Scorecard developed by WestfaliaSurge, using a 4-point scale to assess the degree of manure and bedding contamination at the teat end after completion of the preparation procedure, prior to unit attachment.



Quantitative Assessment of Teat End Contamination

Several attempts have been made to quantify bacteria numbers on teats before milking using swabs or rinses combined with subsequent plate culture methods. More recently, bioluminescence assessment methods have been described. The need to assess automated teat cleaning in robotic milking systems has spurred activity in this area. Slagjuis et al, used both a cobalt tracer (2004a) and poppy seeds (2004b) mixed with manure and manually applied to teats before cleaning to assess efficacy of teat cleaning. Meline et at. (2004) used *Clostridium tyrobutyricum* spores added to a manure slurry and applied to teats before cleaning to assess removal rates.

Knappstein et al. (2004) reported on the use of both total bacteria counts and ATP measurements of teat swabs for assessing teat cleaning efficacy. They recommended an ATP based method as a pragmatic evaluation of teat cleanliness on farms with either automatic or conventional pre-milking preparation. To date, these methods have not found wide application for routine field use because of their cost, complexity, large cow-cow variability and/or considerable variability introduced by small changes in sample technique. Efforts are underway to develop improved methods that are easier to use in the field and yet provide useful information on the real bacterial challenge at the teat end.

Summary

The dairy industry in North America continues to face the daunting task of reducing new intra-mammary infection rates from the environment. The changing face of the industry has not helped our chances of improving hygiene. However, armed with some of the tools described in this article, the investigator can determine the extent of manure contamination and the reasons for it, evaluate the bedding material as a risk for infection, determine the effectiveness of teat end preparation before milking, and monitor the sources of contamination of the bulk tank milk with environmental pathogens. With these quantitative tools, interventions can be targeted at the most appropriate areas on the farm and subsequent progress monitored.

References

Abe, N. 1999. The deeper the "mud", the dirtier the udder. Hoard's Dairyman 144: 439.

Barkema, H.W., Y.H. Schukken, T.J.G.M. Lam, M.L. Beiboer, G. Benedictus, A. Brand. 1998. Management practices associated with low, medium and high somatic cell count in bulk milk. J Dairy Sci 81: 1917-1927.

Barkema, H.W., J.D. Van der Ploeg, Y.H. Schukken, T.J.G.M. Lam, G. Benedictus, A. Brand. 1999. Management style and its association with bulk milk somatic cell count and incidence rate of clinical mastitis. J Dairy Sci 82:1655-1663.

Bartlett, P.C., G. Y. Miller, S. E. Lanc, and L. E. Heider. 1992. Managerial determinants of intramammary coliform and environmental Streptococci infections in Ohio dairy herds. J Dairy Sci 75:1241-1252.

Bodoh, G.W., W.J. Battista, L.H. Schultz. 1976. Variation in somatic cell counts in Dairy Herd Improvement milk samples. J Dairy Sci 59:1119-1123.

Brito, JRF, MAV Paiva e Brito, and R da S Verneque. 2000. Bacterial counts on the surface of the teats of cows milked under different methods of udder preparation, including cows milked by hand and stimulated by suckling a calf. Ciencia Rural 30(5):847-850

Cook, N. B. 2002. The influence of barn design on dairy cow hygiene, lameness, and udder health. Pages 97-103 in Proc. of the 35th Ann. Conv. Amer. Assoc. Bov. Pract., Madison, WI. Amer. Assoc. Bov. Pract., Rome, GA.

Cook, N.B. 2004. The cow comfort link to milk quality. Proc. NMC Regional Meeting, Bloomington, Minnesota. June 29-30. pp 19-30.

Cook, N.B. 2006. Sand bedding and coliform mastitis – a case report. Proc. 45th Annual NMC Meeting. Tampa, Florida. pp 308-309.

Fox, L.K. 1997. Effectiveness of laundering udder cloth towels to reduce mastitis pathogens. J Dairy Sci. 80 (Suppl. 1):234.

Galton, D. M., L. G. Petersson, W. G. Merrill, D. K. Bandler, and D. E. Shuster. 1984. Effects of premilking udder preparation on bacterial population, sediment, and iodine residue milk. J. Dairy Sci. 67(11)2580-2589.

Galton, D.M., L.G. Petersson and W. G. Merrill. 1986. Effects of premilking udder preparation practices on bacterial counts in milk and on teats. J. Dairy Sci. 69(1)260-266.

Gaworski, M. A., C. B. Tucker, D. M. Weary, and M. L. Swift. 2003. Effects of stall design on dairy cattle behavior. Pages 139-146 in Proc. Dairy Housing Conf., Fort Worth, Texas. Amer. Soc. Agric. Engineers, St Joseph, MI.

Hassan, L, HO Mohammed, RN Gonzalez, PL McDonough, MV Thrusfield, and EA Goodall. 1999. Milking practices associated with the presence of Listeria monocytogenes in New

York State dairy farms. Proceedings of the Society for Veterinary Epidemiology and Preventive Medicine Meeting 1-7;

Knappstein, K, N Roth, HG Walte, J Reichmuth, BA Slaghuis, RT Ferwerda-van Zonneveld, and A Mooiweer. 2004. Effectiveness of automatic cleaning of udder and teats and effects of hygiene management. EU Project Automatic Milking Deliverable D14.

Melin, M, H Wiktorsson, and A Christiansson. 2004. Teat Cleaning Efficiency Before Milking in DeLaval VMS Versus Conventional Manual Cleaning. Automatic milking - A better understanding., 117. Wageningen, The Netherlands: Wageningen Academic Publishers

Neave., F.K., F.H. Dodd, R.G. Kingwill. 1966. A method on controlling udder disease. Vet Rec 78:521-725.

Pankey, J. W., E. E. Wildman, P.A. Drechsler, and J. S. Hogan. Field trial evaluation of pre-milking teat disinfection. 1987. J Dairy Sci., 70:867-872

Rasmussen, MD, DM Galton, and LG Petersson. 1991. Effects of pre-milking teat preparation on spores of anaerobes, bacteria, and iodine residues in milk. Journal of Dairy Science 74(8):2472-2478.

Rasmussen, M.D. 2000. A review of milking preparation: the science. Proc. 39th Annual Meeting, National Mastitis Council, Albuquerque, NM, pp 104-110.

Reneau, J.K., A.J. Seykora, B.J. Heins, M.I. Endres, R.J. Farnsworth and R.F. Bey. 2005. Association between hygiene scores and somatic cell scores in dairy cattle. JAVMA 227: 1297-1301.

Ruegg, P.L. and I. R. Dohoo. 1997. A benefit to cost analysis of the effect of pre-milking teat hygiene on somatic cell count and intra-mammary infections in a commercial dairy herd. Can Vet J., 38:632-636.

Ruegg, P., M.D. Rasmussen and D. Reinemann. 2000. The seven habits of highly successful milking routines. A3725 UW Extension publications, Madison, WI. 7p.

Schreiner, D.A., and P.L. Ruegg. 2003. Relationship between udder and leg hygiene scores and subclinical mastitis. J. Dairy Sci. 86: 3460-3465.

Slaghuis, BA, RT Ferwerda-Van Zonneveld, MC te Giffel, and G Ellen. 2004a. Cobalt as a Tracer for Estimation of Residues in Milk after Application of Automatic Teat Cleaning Systems. Automatic milking - A better understanding., 119. Wageningen, The Netherlands: Wageningen Academic Publishers.

Slaghuis, BA, RT Ferwerda-Van Zonneveld, and A Mooiweer. 2004b. Cleaning Effects of Teat Cleaning in Robotic Milking Systems by Use of Poppy Seed as Tracer. P 118. Automatic milking - A better understanding., Wageningen, The Netherlands: Wageningen Academic Publishers.

Ward, W.R., J.W. Hughes, W.B. Faull, P.J. Cripps, J.P. Sutherland and J.E. Sutherst. 2002. Observational study of temperature, moisture, pH and bacteria in straw bedding, and fecal consistency, cleanliness and mastitis in cows in four dairy herds. Vet. Rec. 151:199-206.

Zdanowicz M, Shelford JA, Tucker CB, Weary DM, von Keyserlingk MAG. Bacterial populations on teat ends of dairy cows housed in freestalls and bedded with either sand or sawdust. J Dairy Sci 87: 1694-1701, 2004