Evaluating Herd Milk Quality Using DHI Somatic Cell Counts

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Introduction

The somatic cell count (SCC) option is now widely selected by dairy producers in the DHI program for monitoring udder health. This is an excellent program because it provides the opportunity to evaluate the extent of subclinical mastitis in the herd and if needed, some reports may be generated to help diagnose the source of the mastitis. This is an opportunity for more profitable dairying since it is known that SCC are the single most important factor in accounting for variation in DHI herd average milk production (25). Before going any further it is important to discuss mastitis in terms of the bigger picture. Without covering some of the basic aspects of mastitis and the terminology that goes with it, understanding the management information in the DHI reports will be difficult. The points that need brief discussion to introduce this topic are the cause of mastitis, natural defense mechanism to udder infection, major forms of mastitis, and the economics of the disease. Excellent texts with an overview of mastitis are Current Concepts of Bovine Mastitis (2) and the Winning the Fight Against Mastitis (20).

Basics of Mastitis

Mastitis is an inflammation of the mammary gland. The source of that inflammation is usually microorganisms that gain access to the mammary gland through the orifice of the teat end. Microorganisms that cause disease are called pathogens. In mastitis control programs, these organisms are categorized as either contagious or environmental pathogens. Like any disease caused by bacterial infection, mastitis is a numbers game. Greater bacterial exposure translates to a greater rate of infection and more mastitis. To date, most of the progress in controlling mastitis has resulted from reducing exposure of cow's teats to pathogens, and from the widespread use of antibiotics. That is why management plays such a big part in this disease. Dr. Jim Jarrett, regular writer for the Cowside Practice column in Hoard's Dairyman, sums mastitis control up in three words: clean, dry, and comfortable. All of these are under the direct control of the manager. Controlling bacterial infection also involves the mammary gland's resistance to infection. Two examples of steps which may be taken to improve resistance to infection are supplementing the cow's diet with the micronutrients or minerals and vaccination against coliform mastitis.

The natural defense of the cow to udder infection calls the immune system into action. When the tissue in the udder senses a foreign body and the irritation that accompanies the pathogenic invasion, white blood cells from bone marrow storage pools are transported to the site of infection via the bloodstream. From the bloodstream these white blood cells migrate into the secretory tissue and in milk to seek out and kill the pathogens. The number of white blood cells which enter the mammary gland depends on the type and number of pathogens which gain access to the udder. The range is from hundreds of thousands to millions of white blood cells. The literature indicates that a SCC of 200,000 from an individual quarter or cow is the upper limit for normal milk from uninfected quarters. Thus, a 200,000 SCC is a threshold that may be used to distinguish infected cows from uninfected cows

The term SCC is used rather than a white blood cell count because it includes both epithelial cells sloughed from the milk duct of the udder and white blood cells. Approximately 15-17% of the cell count from uninfected cows are sloughed epithelial cells and the remainder are white blood cells (17). In uninfected quarters, macrophages and

neutrophils each make up about 30% of the somatic cell count and lymphocytes 25%. But in quarters with subclinical and clinical mastitis a shift in cell type takes place such that approximately 90% of the cells are neutrophils (3,18). Neutrophils are the primary type of white blood cell which seeks out, engulfs, and digests pathogens.

Three forms of mastitis which are commonly discussed are subclinical, clinical, and chronic. Subclinical mastitis is not discernable with the naked eye. The milk and udder appear normal yet the milk composition has changed. The primary change which is measured is the increase in concentration of white blood cells or SCC. Cowside tests such as the California Mastitis Test may be used to detect this type of mastitis. DHI laboratories use electronic counters. Symptoms of clinical mastitis are flakes, clots, or blood in the milk, a swollen quarter, or perhaps an increased body temperature or other symptoms affecting the cow's body. Chronic mastitis is characterized as mastitis of long duration. Usually episodes of clinical mastitis appear sporadically but in the intervening periods between clinical episodes, the udder infection only subsides to the subclinical form of the disease. The DHI SCC does not estimate clinical mastitis. It is a system to determine the extent of subclinical mastitis or the development of new udder infections. Chronic mastitis may also be measured depending on the processing center and type of custom report generated.

It is estimated that the economic cost of mastitis is $184.40 per cow per year (2). Subclinical mastitis caused the largest proportion (66%) of the cost because this form of the disease reduces milk production. Although costs associated with clinical cases such as additional culling, veterinary, and medicine costs are direct out-of-pocket expenses, together they only represent 34% of the total cost. Milk production is still the number one economic loss. A recent article in 2002 by S. L. Ott (15) reported that the average bulk tank somatic cell count (BTSCC) from 15,806 herds in 14 states. Ninety percent of the herds were located in four states (WI, OH, MI, and PA). Bulk tank somatic cell counts increased each year from 307,000 cells per ml in 1997 to 320,000 cells per ml in 2001 (Table 1). Ott and Novak (16) reported that herds with BTSCC less than 200,000 cells per ml generated $104 per cow more in annual value of production than herds with 200,000 to 399,999 cells per ml and $292 per cow more than herds with 400,000 or more cells per ml.

Arizona DHI values which estimated BTSCC were similar to nationwide statistics (26). For example, the rolling 12 month average herd SCC in August, 2002, for 32 herds on the Provo DHI processing center was 323,000 cells per ml. The rolling 12-month average ranged from 180,000 to 486,000 for these 32 herds. Monthly average for August 2002 of the 22 herds on the SCC program were also reviewed. As expected in the middle of summer heat, August 2002, the average (363,000 cells per ml) and range (246,000 – 508,000) were slightly highly than the 12-month rolling average.

One cost which has been left out of the estimates by the National Mastitis Council are milk quality premiums. Usually the most limiting factor to receiving these premiums are a low SCC and thus, indirectly, managing the herd for low SCC usually has the added economic benefit of milk quality premiums. Dr. John Fetrow has developed a spreadsheet which calculates the economic cost of mastitis on a particular dairy farm (8). This spreadsheet included the premiums for milk quality and the penalty for high somatic cell counts. The attractive aspect of the spreadsheet is that it calculates the mastitis loss relative to goals. That is, it is not reasonable or profitable to eliminate all mastitis and thus all mastitis costs. Rather, there is some baseline level of clinical mastitis, culling, and somatic cell counts that are reasonable for a given farm. When current herd somatic cell count level were inputted in the spreadsheet and a goal level of 150,000 somatic cell count was set for the University of Maryland dairy herd, the major economic loss was the lost milk premiums. Our milk market, Land O Lakes, offers a milk quality program which ranges from -$0.10 to $0.50 per cwt. Maintaining BTSCC between 126,000 and 150,000 pays $0.40 per cwt . While milk loss due to high SCC accounts for the largest economic loss for the majority of herds, it is not difficult to imagine that clinical mastitis, culling and death could be the major sources of economic loss in herds with excellent mastitis control as measured by somatic cell count.

Low Somatic Cell Counts and Risk of Clinical Mastitis

Some dairy farmers have been reluctant to strive for low SCC's in their herds because they fear their cows will be more susceptible to mastitis. Results of Virginia Tech research (4) suggest that animals with low initial SCC's (less

than 100,000 cell per ml) in first lactation have no greater risk of increased mastitis incidences in second and subsequent lactations when compared to animals with higher initial counts. Hogan et al. (10) reported that minor pathogens increased SCC approximately 100,000 to 300,000 cell per ml compared to uninfected quarters but colonization of the udder with these organisms did not prevent infection by environmental pathogens. Matthews and Harmon (11) observed that infection by *Staph aureus*, streptococci, and coliforms also was not prevented in quarters first infected with minor pathogens. Other studies (3, 18) indicate that the SCC level must reach at least 900,000 cells per ml before a cow can reliably prevent udder infection.

A study of Erskine et al. (7) indicates that the rate of clinical mastitis is similar between low and high SCC herds but coliform mastitis is higher in low SCC herds. Eighteen dairy herds with "low" and "high" SCC were selected for six months of study. Twelve herds had 12-month DHI SCC of less than or equal to 150,000 cells per ml (low SCC) and six had a 12-month SCC average of 700,000 cells per ml or greater (high SCC). Quarter milk samples were collected for bacteriologic culture from all cows with clinical mastitis. One of the major findings of the study was that on average there was little difference in clinical mastitis between herds with low (4.23 infections/100 cows/month; range, 0.42 to 10.25 infections) and high (2.91 infections/100 cows/month; range, 1.33 to 3.92) SCC. Notice the range for the low SCC is much greater than high SCC. Thus, some herds with low SCC maintained a very low incidence of clinical mastitis perhaps suggesting superior management. The one major concern, however, was the incidence of clinical coliform mastitis was significantly higher in low SCC than high SCC herds. The authors of the study made no attempt to explain this finding from observations of herd management. But it is well known that clinical coliform mastitis is a management problem. If clinical mastitis is a problem for a producer, it appears that the effective management practices need to be implemented rather than blame the low SCC.

A more recent study (19) from England indicates that producers need to manage the transition cow very carefully. This 12-month prospective study of clinical mastitis was conducted in 482 British dairy herds with a bulk milk SCC of les than 150,000 cell per ml. Clinical mastitis averaged 23.1% of the cows per herd (range 0 to 80). Over 22% of quarter cases occurred in the first 7 days of lactation and over 50% occurred in the first 90 days of lactation. Cluster analysis indicated that the main difference between herds with a low and average incidence of mastitis was the proportion of clinical cases occurring in the first 7 day of lactation, 14% compared with 44%, respectively. Another recent report (5) from Wisconsin indicates that summer is a vulnerable time for fresh cows. In this study of 51 herd the authors found elevations in SCC and prevalence of infection during the summer (July through September) were associated with significant increase in fresh cow and herd new infection rates. These studies point to the importance of excellent sanitation 2 weeks before and around the time of parturition when the cow is very susceptible to mastitis infection. In total, the preponderance of research evidence suggests that the economic benefits reaped from lower SCC should be the decisive factor in a mastitis control program rather than the fear of increased risk of mastitis.

Interpreting DHI Somatic Cell Counts

SCC and Milk Production. Somatic cell counts are reported on DHI SCC in three ways: either as the actual cell count per ml of milk, the weighted SCC, or the linear score (LS) Dr. George Shook, University of Wisconsin, developed and promoted the LS system because it more clearly relates milk yield losses due to subclinical mastitis than actual or raw SCC. The actual SCC is converted to LS using the range for each score in Table 2.

In Table 3, the relationships among LS, SCC and milk yield are shown. Each increase in LS is associated with a decrease in milk production of 1.5 lbs per day or 400 lb per lactation regardless of whether the score increases from 2 to 3 or 7 to 8. Notice, however, that the milk yield loss of first lactation cows is one-half that of older cows. But it should be emphasized that the average lactational LS should be used to accurately calculate milk loss. Loss estimates based on a single SCC test of individual cows are not reliable.

SCC and Infection Status. Somatic cell count has been accepted as the best quantitative index of inflammation in the bovine mammary gland. The primary factor affecting somatic cell counts is infection status. Based on a number of studies the uninfected quarters have the lowest cell counts, those infected with major pathogens have the highest cell counts and minor pathogens elicit a cellular response slightly greater than that found in uninfected quarters (Table 4).

Common Misinterpretations. There is a long list of factors other than intramammary infection that can be blamed for deteriorating udder health. Studies from the scientific literature support the idea that several factors are associated with changes in herd SCC (21). Such things as age of the cow, stage of lactation, season, stress, stray voltage, herd health, day-to-day variation, and estrus may all be related to SCC changes. But the relationship between these factors and the SCC is not cause-and-effect. The principle to remember is that these other factors may exert an effect on the SCC but only if the cow or herd also harbor intramammary infection.

Age and Stage of Lactation. On the DHI-SCC reports, the cell count LS is routinely categorized by age and stage of lactation. To aid in the interpretation of these two factors, the results of a study by Sheldrake et al. (23) are helpful. SCC remain low (100,000 to 200,000 cells per ml) regardless of age. Quarters infected with minor pathogens have SCC of 200,000 to 500,000 and in *Staph aureus* infected quarters, the SCC ranges from 500,000 to 2 million. Next to infection, lactation number has the greatest influence on SCC and consequently, a review of the older cows DHI SCC record is one good place to look for the source of a mastitis problem and for potential culls.

Within lactation, the SCC for uninfected quarters is inversely related to the lactation curve (Figure 2). The SCC is elevated at freshening, lowest at peak to mid-lactation and rises in late lactation. The amount of change in SCC of uninfected cows, however, is small. In Sheldrake's study, the SCC increased only 80,000 – from 83,000 cells per ml at 35 days postpartum to 160,000 cells per ml at 285 days postpartum. Thus, when interpreting the lactation trends on DHI-SCC report, we should expect no, or minimum, increases across a lactation in a herd with an effective mastitis control program.

Diurnal SCC Variation. Reneau (21), in his review of the SCC literature, reports that the one valid concern when interpreting DHI SCC are those dairy producers on a.m.-p.m. testing (where only one milking is collected). Studies quoted in the review indicate a diurnal variation of 2 to 5-fivefold due to time of sample collection. A problem that dairy producers on the a.m.-p.m. DHI SCC program may encounter is the misclassification of uninfected cows since an increase over a fairly low threshold will suggest a new infection. The diagnosis of cows infected with major pathogens should not be affected by diurnal variation in SCC.

Threshold Somatic Cell Count. This term does not appear on the DHI SCC report but it is implied in the way that the data are categorized on SCC reports. The threshold SCC is a value that theoretically separates uninfected cows from the infected animals. Reneau from Minnesota, reviewed the literature and concluded that using 283,000 SCC (DHI LS of 5 or greater) as a threshold is 75 to 80% efficient in correctly classifying infected and uninfected animals (21). This criteria is used in the Provo Record Processing Center (*Table 5*).

North Carolina Dairy Records Processing Center has 5 categories on the monthly herd summary. In their literature, they stress the relationship of SCC to milk yield rather than to infection status *(Table 6).*

When reviewing the DHI SCC report it is important to remember that the threshold values used to distinguish one category from another were set to facilitate analysis and interpretation of the data. The threshold is not an infallible test that establishes the presence or absence of infection in every case. Eberhart et al. (6) reported the probabilities of a cow being infected with minor and major pathogens at a given DHI-SCC *(Table 7).*

The conclusion one can draw from the above data is that a threshold set at any of the seven SCC levels would have two types of errors associated with it: false positive and false negative results. At the low end of the SCC range, false positives would be anticipated for major pathogens and a high proportion of false negatives for minor pathogens. Conversely, at the upper end of the SCC range, few false positives would happen for major pathogens or false negatives for minor pathogens. Therefore, it becomes apparent that on the basis of infection probability, there is no perfect threshold level. The rationale behind choosing the thresholds in the DHI-SCC program is that they are levels that are useful in monitoring a dairyman's mastitis control procedures. Other purposes for setting threshold SCC could be culling, culturing, and treatment (i.e. selective dry cow therapy). And each of these purposes could have different thresholds depending on the amount of confidence desired in making a correct choice.

Prevalence. This is the number of existing infections and their duration. It is another tem that does not appear on the DHI SCC report but is implied depending on the source of the records. Prevalence, or level of mastitis, is a relatively static measure of herd mastitis and because it changes slowly, may not reflect recent management changes

that the farmer has made. Infections of contagious organisms last weeks or months and consequently, prevalence is more indicative of contagious than environmental mastitis. Prevalence of environmental streptococci and coliform rarely exceed 10 and 5%, respectively.

Goals for prevalence can be presented as % Low (Provo records) or in LS. Suggested goals are stated in (*Table 8*).

New Infection Rate. Improved management or deteriorating udder health should be immediately reflected in this parameter. Sixty percent of environmental streptococci and 69% of coliform infections last less than 30 days. Thus, new infections are probably more important for environmental than contagious mastitis since duration of infection is short. Provo records present this information on the monthly herd report on the somatic cell summary section near the upper left hand corner. Under the column abbreviated CHG. 5, the two sub-headings are % UP and % Down for lactation number 1, 2, 3+ and Total. The new infection rate would be indicated in the % UP column. Any significant rise in this category would indicate that the new infection rate is increasing.

If advanced DHI computer programs with graphic capabilities are available, more in-depth analyses may be conducted. Trend graphs can provide producers and their advisors with a picture of what is occurring in their herds. Graphing linear score versus days in milk (by lactation group) provides a detailed picture of where, in the production cycle, infections are occurring

Scatter graphs may be used to graphing test day linear score (LS) by previous linear score (PLS) clearly illustrates the distribution of animals in one of four groups. Those groups include non-infected animals (LS < 4.0 and PLS < 4); newly infected animals (LS > 4.0 and PLS < 4.0); cured animals (LS < 4.0 and PLS > 4.0); and chronic animals (both LS and PLS > 4.0). This graph can be examined over time to determine whether performance is getting better or worse? If a large number of chronic cows exist within the herd, look for an infectious organism. If new infections are high, as well as the number of cured animals, examine environmental conditions and milking procedures.

Diagnostic Uses of DHI SCC Using Paper Records

The two general types of paper records that should be reviewed to determine the status of the herd's udder health are the Monthly Herd Summary and Individual Cow Records. These may be separate reports or combined into one depending on the record processing center. The Herd Summary should be used to evaluate the overall management such as heifer, dry cow and lactation management. Once these areas have been reviewed, more specific decisions can be made from the individual cow records.

Probably the most important point to remember when attempting to make diagnoses from DHI-SCC is that one needs to study the trends over time. A single SCC on one cow or even a single herd summary for one month on the herd has limited value. But the trends that emerge from several months of DHI-SCC testing are meaningful and useful diagnoses can be made from them.

Monthly Herd Summary

Overall Management. The annual summary should indicate the prevalence of mastitis or economic loss during the year and whether the trend in mastitis control is maintaining current progress, improving or worsening over time. If mastitis is more prevalent during certain seasons of the year, this also should be evident from reviewing these results. Further study of the current monthly data are helpful in evaluating more specific areas of management.

Heifer Management. One very important concept in mastitis control is that overall udder health can be no better than the current status of the heifers. Dairy producers must excel in this area to maintain an excellent udder health program. The prevalence should be extremely low as indicated by the percent low or average LS. In addition, the first LS average in the stage of lactation summary should be low and remain low for the duration of lactation. If the first test consistently is above 3.0, then calf housing and raising practices and the maternity care for these animals needs evaluation.

Dry Cow Management. This area of management can be evaluated using the first test for stage of lactation. If the average LS consistently exceeds the monthly average for the herd or is as high as the last stage of lactation LS, dry cow management may need attention. Such practices as drying off strategy, administration of dry cow therapy, housing and environment, maternity care, and number of chronic mastitis cows could be at fault.

Lactation Management. The trends in LS for each stage of lactation and lactation number should be evaluated to determine whether milking management might be the area needing management changes. Since most first lactation cows are usually uninfected, they will be most sensitive to deficiencies in milking management, particularly if contagious mastitis is involved. If new infections are developing during lactation in this group, these will be reflected with higher LS (higher than first stage of lactation LS), particularly in mid lactation. The exact amount of change in LS during lactation is difficult to define. Another important point to consider are the number of cows represented in each category and stage of lactation. Averages of small numbers can obviously be misleading. It also would be helpful to review several of the last herd summaries to increase your confidence when drawing conclusions.

Individual Cow Data

Potential uses of individual cow records are culling, early dry-off, segregation and withholding of milk from high SCC to ensure payment of milk quality premium.

Culling. Candidates for culling would be those that run consistently high (LS of 6 or greater) and do not respond to dry cow therapy. *Staph aureus* cows in this category should be at the top of the cull list.

Early dry-off. Cows that are consistently running a high SCC and have a high potential for milk production or breeding stock may merit early dry-off. The objective is similar to that of culling since this practice removes the source of infection and high SCC from the lactating herd. This option probably has limited value for most dairy producers.

Segregation. My experience in Maryland is that dairy producers will not, as a rule, segregate cows (flat barn or parlor herds) on the basis of DHI SCC. The more practical alternative has been to visually identify those cows with a legband and backflush the milker with a sanitizer solution.

Withholding Milk. An individual cow can account for a significant percentage of the total bulk tank SCC. Management reports can be ordered to determine what contribution high SCC cows are making to the BTSCC. Usually it is not economical to cull a cow due to high SCC because the value of her milk is greater than premiums gained by removing the high SCC cow. But it will usually be a good decision to cull very high SCC cows if replacements are available.

Use of Individual DHI SCC for Treatment

Lactational antibiotic treatment based only on high SCC is not recommended and will yield disappointing results. Research at Cornell University (12), University of Wisconsin (27), and Virginia Tech (22) has demonstrated that this practice *does not* increase milk production or eliminate udder infections which cause the high SCC.

SCC Not a "Stand Alone" Tool

The DHI SCC are not a stand alone diagnostic procedure for evaluating udder health. It is, however, a good place to start in when reviewing the effectiveness of the dairy producer's mastitis control practices. But realistically, if the DHI-SCC results do indicate potential problems, then data from other procedures such as bulk tank or individual

cow cultures, milking machine evaluations and observations from a herd visit must be included before specific conclusions and recommendations can be made for an individual herd.

Two examples in the literature illustrate why data other than SCC are required to diagnose mastitis problems. Hoblet et al. (6) made a presumptive herd diagnosis of environmental mastitis on the basis of observed nature of clinical mastitis and consistent history of low DHI SCC (87% of cows <283,000) and bulk tank SCC (annual average 137,000). Yet results of their study indicated that coagulase-positive Staphylococci, including *Staph aureus*, were repeatedly cultured from cows with SCC less than 200,000 cells per ml. Thus, bacteriologic culture was necessary to accurately diagnose the source of the mastitis even though SCC profiles suggested contagious mastitis was unlikely. Another example is the finding of McDonald reported at the 1989 Annual National Mastitis Council Meeting (10). His experience indicates that in 12 large Washington herds that were monitored over a two-year period that one-half of *Staph aureus* infected cows had individual SCC of less than 300,000. He suggests that culling based on DHI SCC would be less than ideal and that bacterial culture is a wise practice, especially with the advent of the new Pro-Staph antibody test available through DHI, before making any culling decisions based on mastitis.

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Table 1. Trends in Bulk Tank Somatic Cell Counts (BT SCC) Among 15,806 Herds, 1997-2001.

Year	BT SCC 1000's
1997	307
1998	310
1999	312
2000	315
2001	320

Reference: S.L. Ott (15)

Table 2. SCC that correspond to linear score

	Cell Counts ($X10^3$)	
Linear Score	Midpoint	Range
0	12.5	0-17
1	25	18-35
2	50	35-70
3	100	71-140
4	200	141-282
5	400	283-565
6	800	566-1,130
7	1,600	1,131-2,262
8	3,200	2,263-4,525
9	6,400	4,526-

Table 3. Milk loss estimates from linear score

		Milk Yield Loss		
		lb/day[1]	lb/lactation	
Linear Score	**Mid-point SCC**		**First Calf**	**Older Cows**
2	50	0	0	0
3	100	1.5	200	400
4	200	3.0	400	800
5	400	4.5	600	1,200
6	800	6.0	800	1,600
7	1,600	7.5	1,000	2,000
8	3,200	9.0	1,200	2,400

[1]Losses in first lactation are one-half these amounts.

Table 4. Summary of Mean SCC or SCC Range by infection status among several studies

	Mean SCC or SCC Range		
Reference	**Uninfected**	**Minor**	**Major**
Schultz, 1977 (19)	170,000	227,000	998,000
Eberhart et al., 1979 (4)	165,000	364,000	1,061,000
Natzke et al., 1972 (11)	214,000	. . .	504,000-1,470,000
Sheldrake et al., 1983 (18)	100,000-175,000	200,000-500,000	500,000+
Andrew et al., 1983 (1)	147,000	. . .	556,000

Reference: J.K. Reneau (21)

Table 5. DHI-Provo Threshold Standard's for Infection Status

SCC Category	Linear Score	Interpretation
Low	0-4	Noninfected
Medium	5-6	Infected
High	7-9	Infected

Table 6. North Carolina Threshold Standards.

% of cows with Linear Score (LS) in each of five categories

LS	0, 1, 2, 3
LS	4
LS	5
LS	6
LS	7, 8, 9

Table 7. Probability of infection with minor and major pathogen at various concentrations of somatic cell counts.

SCC $X10^3$	Probability of Minor Pathogen	Probability of Major Pathogen
<100	.48	.06
100-200	.59	.17
200-300	.50	.34
300-400	.44	.45
400-500	.35	.51
500-600	.28	.65
>600	.19	.79

Reference: Eberhart et al. (6).

Table 8. Goals for % Low and Linear Score on Provo DHI Records.

% Low (Linear Score 0-4)	Linear Score	Rating
≥90	1.0-2.5	Excellent
80-89	2.6-3.2	Good
70-79	3.3-3.8	Average
60-69	3.9-4.4	Below Average
<60	≥4.5	Poor