



# Comment on S. Sarac and C. Sensogut's paper: A statistical determination of methane emission from coalbeds—case study

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At first I read this paper with interest, which grew to fascination, and ended up with horror. Such reactions to a supposedly scientific contribution are rare, and I believe the coal mining community must be warned in the strongest possible terms against the recommendations that this paper makes.

The paper purports to have assessed statistically two sets of data on methane concentrations recorded in the return air from Turkish longwalls. The first set of data, from their Table I, is reproduced in Table I below.

The data have been rearranged in classes to indicate the underlying distribution. While there is only limited data ( $N=33$ ), the distribution looks as if it could be the sum of two normal distributions with means around 0.5 and 0.8, or possibly a log-normal distribution. What is quite clear is that it is **not** a single normal distribution.

However, the authors blithely apply a normal model to the data, and calculate a mean and standard deviation as if the distribution were normal. Their mean value of 0.671 appears to be in error—the data in Table I below have a mean value of 0.668. This may indicate some errors in transmission. I checked that I had captured the data in the original Table I correctly.

Moreover they calculate a standard deviation as  $\sqrt{[(\sum X_i^2)/n]}$  according to their Equation [2], which is clearly incorrect and, in any event, is inappropriate for the estimation of the standard deviation of a small population. If the data were normally distributed, then the estimate of the standard deviations would be:

$$s = \sqrt{[(n\sum x^2 - (\sum x)^2)/(n(n-1))]}$$

but as it is not normally distributed, it is not valid to calculate a standard deviation at all.

They then make matters worse by calculating (correctly, this time—but no more validly) a 'standard error',  $S_x = s/\sqrt{n}$

which is the estimate of standard deviation of the estimate of the mean, and **apply this to determine the probable error of the whole population**. 'In this case the upper confidence limit is determined as  $UCL = 0.6712 + 1.96 \times 0.0354 = 0.7406$ . By taking this value as the methane concentration rate, the probability of which the value of the methane concentration is lower than the UCL at any time is about 2.5%.' This is just not true—there is a 95% probability that the **average** methane concentration is less than this value, not a 95% probability that the **individual values** are below 0.7406. Indeed, mere inspection of Table I above shows that 11 values, one-third of the total, are above their so-called 'upper confidence level.'

They conclude that they can reduce the airflow from the value required for the highest recorded level (which is 55% above what it would be at the average value) to 9% above the average value, with a significant saving in the energy cost of ventilation. Of the risks of explosion that might result from following their prescription, they are mercifully silent.

There is ample evidence of explosions in Turkish collieries without any need for flawed statistical treatment of limited data. Fortunately the Turkish authorities have had some success since the Kozlu disaster of 1992, when over 250 died. There was a comparatively minor disaster at Sorgun in 1995, when 'only' 20 died, and two informal miners were killed at Zonguldak in 2000, but in general the recent record has been a great improvement on an unfortunate history.

The authors might have benefited from greater contact with the Technical University in Ankara, where the Head of Mining Engineering, Dr. Güyagüler, is a world-recognized authority in the field (see, for instance, references 1, 2 and 3).

The publication of this paper raises serious questions over the Institute's policy of publishing papers of 'general and topical interest.' It is not enough to note that the paper has not been refereed. The caveat that 'Care must be taken of the statistics and the probability that high methane concentrations could lead to dangerous situations being present' suggests that coal mine safety is not as high on the Institute's list of priorities as it should be. Perhaps Council needs to revisit the policy regarding this kind of paper.

## References

1. GÜYAGÜLER, T., and BOZKURT, R. Cost of Mine Accident in Coal Mine. *Transaction of 8th Coal Congress of Turkey*, Zonguldak. May, 1992, pp. 331–344.
2. GÜYAGÜLER, T., ÖNDER, Y., and BOZKURT, R. Statistical and Economical Analyses of Accidents in Coal Mines. *Transaction of 13th Mining Congress of Turkey, Ystanbul*. May.1993, pp.102–113.
3. GÜYAGÜLER, T. Analyses of Firedamp Explosions in Turkey and suggested preventive measures, Turkey. *Proceedings of 13th Coal Congress of Turkey*, Zonguldak. 29–31 May. 2002, pp. 45–52.

Table I Measured values of methane sample								
Methane in % - class ranges								
0.3-0.39	0.4-0.49	0.5-0.59	0.6-0.69	0.7-0.79	0.8-0.89	0.9-0.99	1-1.09	1.1+
0.32	0.45	0.52	0.62	0.71	0.82	0.92	1.02	1.15
0.38	0.47	0.53	0.62	0.76	0.82	0.94		
	0.49	0.54	0.62	0.77	0.82	0.96		
		0.55	0.63		0.86			
		0.56	0.65					
		0.57	0.65					
		0.57						
		0.58						
		0.58						
		0.59						

## Reply to P.J.D. Lloyd's comment by S. Sarac and C. Sensogut

These are our comments on the critique presented by P. Lloyd, which we feel are inappropriate.

- 1) First of all, a data set of 30 is accepted as the threshold limit in statistics. In the case where, the number of data is over 30, it is called a large population. In the work published in the April issue, a data set of 33 was used. It should, of course, be pointed out that the more the number of data, the better the confidence of the work. The larger sum of data collected over a longer period would give the methane content of the seam in a more confident manner. The case study given within this work aimed at explaining the statistical thinking used in it.
- 2) The distribution of the data in hand gave an acceptable result with the  $\chi^2$  test used to see the compliance with the normal distribution. In the case of the collection of more data, the distribution is thought to get closer to the bell-shaped curve.
- 3) The statistical analysis of the data was carried out by the employment of the well-known software, STATISTICA. Although the original data had values to four decimal places, the data in the paper were rounded to two decimal places. The mean value of the rounded data is calculated as 0.66875. However, the mean value of the original data is 0.671. Therefore, the mean value is correct as it appeared in the paper.
- 4) Equation 2 is mistakenly given as

$$s = \sqrt{\frac{\sum X_i^2}{n}}$$

It should have been given as

$$s = \sqrt{\frac{(X_i - \bar{X})^2}{n}}$$

Apart from this error, the rest of the formulation given in the text can be verified from any basic statistics book.

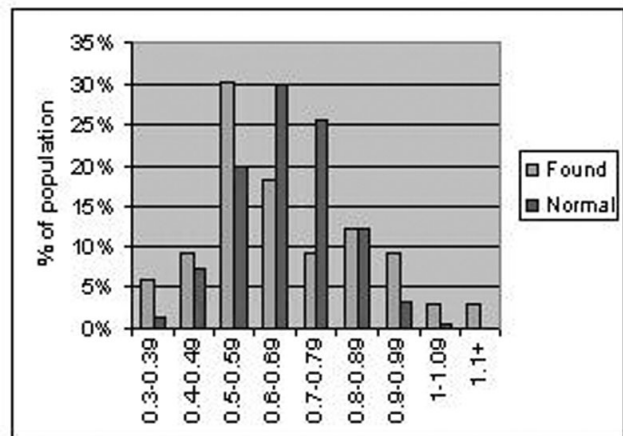
- 5) It is also inappropriate to criticize the utilization of the upper confidence limit instead of the highest data which are supposed to create unsafe ventilation conditions as the value of airflow calculated is already multiplied by a certain coefficient of confidence.
- 6) As a result, the basic philosophy of the method given in the paper is certainly correct. It is also inevitable that there will be criticism for every new approach. However, we sincerely suggest the reviewer examines the chapter on 'confidence passage' in any basic statistics book.

## P.J.D. Lloyd replies to comments made by S. Sarac and C. Sensogut:

- 1) This depends entirely on the type of distribution. The claim is probably valid for a normal distribution, but I would be most hesitant to estimate a log-normal distribution from as little as 30 data points, and there is clear evidence that this distribution is **NOT** normally

distributed. For normal data sets, Student's T applies to fewer than 20 points.

- 2) I have done a  $\chi^2$  test to see if the data are normal. My calculations are appended in the form of an Excel spreadsheet. For 8 degrees of freedom,  $\chi^2=0.9527$ , which means the probability of the distribution being normal is less than 0.5%, i.e. it is 99.5% certain that the data are **NOT** normally distributed. They have not offered any values of their  $\chi^2$  test, so it is not possible to determine how they found an 'acceptable' result. The comparison of their data distribution with a normal distribution makes the problem clear:



In this graph the normal distribution shown is calculated for a mean of 0.669 and a standard deviation of 0.190, which are the calculated values for the data set.

- 3) I will accept this with reservations—instruments robust enough to be used in mines rarely have '4 decimal place' accuracy, and rounding does not usually introduce such a large error.
- 4) Not adequately accented in any 'basic statistics book' is the need to check that the population from which the sample is drawn is normally distributed. Plug and play formulation is always to be avoided where human life is at risk—as it is in this case. A thorough knowledge of statistics is necessary if catastrophe is to be avoided—one cannot, indeed, should not, rely on any 'basic statistics book'. Nor should one use a package such as **Statistica** without a good understanding of statistics in the first place. There is always a risk of using the package inappropriately.
- 5) I believe the authors are using a circular argument at this point. It is not clear what they mean when they say 'as the value of airflow calculated is already multiplied by a certain coefficient of confidence.' However, it is probable that they mean that the airflow is set to ensure that there is a high probability that the methane concentration in the air will not approach the explosion limits. They have then measured the methane concentrations and duly reported them. They have then, incorrectly in

my opinion, estimated an upper confidence limit to the methane concentration. I say 'incorrectly' because, firstly, they have assumed their data is normally distributed and it isn't, so normal statistics should not be applied; and secondly they have used the variance of the estimate of the mean, rather than the variance of the population, to determine the upper confidence level. They then say it is 'inappropriate' to criticize the use of the upper confidence level because the air flow is safe in any event! I estimate that application of their procedure at constant airflow would increase the risk of methane explosion over 1000-fold because of their two basic errors.

**The authors: S. Sarac and C. Sensogut, have a query as their final comment, for P.J.D. Lloyd**

What is the expectation on the methane measurement values taken in a small time span? Do these values take place in normal or log-normal distribution?

**P.J.D. Lloyd, replies:**

My response to their question is found in the data in their paper. The data from Table I are **NOT** normally distributed. A log-normal model is not a bad fit; a bimodal normal model is slightly better, but statistical tests cannot really distinguish between the two (log-normal and bimodal). However, the data are clearly **NOT** normal.

The really critical point, however, is that whether the distribution is log-normal or bimodal doesn't really matter—what matters is that both point to a significantly enhanced risk of entering the methane explosion limits, relative to the risk if the distribution were normal and the usual safety factors were applied. The risk of entering the explosion limits is further increased if, in addition to employing the wrong model for the data, the control point is increased to the upper level calculated from the error on the mean, as suggested. ♦

## SANS 1915: Backfilling a gap in mining safety

Backfill bags are not new to the South African mining industry, having been in use for more than 30 years. Today, some twenty-two local mines use backfill as part of their hangingwall/regional support system.

Until the publication of SANS 1915, *Woven backfill bags and paddock curtains*, there was no single standard against which the quality of backfill bags could be benchmarked and their quality monitored. Matters came to a head when a backfill bag burst, and a miner was killed in the ensuing mud-rush.

'The value of the standard is that it provides for, among other things, a single test method against which the manufacturers and users of backfill bags can base a quality management system on' said Michael Dunn, Rock Engineering Manager (Technical) of AngloGold. 'This will enable the local mining industry to implement a quality management system for backfill bags that complies with the new mining regulation 14.1,' he concluded.

Mining regulation 14.1 states that 'At every underground mine where a risk of rockbursts, rock falls or roof falls exists, the employer must ensure that a quality assurance system is in place which ensures that the support units used on the mine provide the required performance characteristics for the loading conditions expected.'

'This is another standard produced by Standards South Africa that helps improve safety in our mines' said Dr Cliff Johnston, Divisional Director of Standards South Africa, the standards-generating arm of the SABS. 'We have come a long way since the first attempts at standardization in the mining industry nearly a century ago'.

'To an increasing extent, deep level mining in our gold and platinum mines literally rests on backfill' said Mark Grave, of the CSIR's Miningtek. 'Studies show that the use of backfill is an essential part of mining at depths greater than three kilometres'.

'While it is important that backfill bags comply with a certain minimum quality and safety standard, our studies show that matching the drainage and strength characteristics of the bags with the application for which they are intended is vital to mine safety' he concluded.

*For further information on the standard please contact:*

Mark Grave, CSIR Miningtek, Tel: (011) 358-0077),  
Fax: (011) 726 5405, or email: mgrave@csir.co.za

*To purchase the standard, please contact:*

The SABS's Standards Sales Division, Tel: (012) 428-6883,  
Fax: (012) 428-6928, or email: sales@sabs.co.za ♦

