A statistical analysis of accidents to Bantu personnel in the Gold Mining Industry

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SYNOPSIS

An analysis was made of records of accidents involving Bantu mineworkers and which resulted in either minor injuries or hospitalizations to determine patterns in underground accidents from which to formulate priorities in accident prevention in gold mines.

The results showed that:

(i) specific labour categories, such as inexperienced men, are exposed to certain types of hazards the extent of which warrant the separate design of safety programmes to meet their specific needs;

(ii) the systematic study of minor accidents provides a dependable source of information of which safety departments could make greater use in their efforts to control and prevent mining accidents.

INTRODUCTION

An analysis of accident records provides a useful means for identifying patterns in the incidence of accidents in large populations. Supplemented by the examination and evaluation of isolated variables likely to be related to accidents, it has also been used in studies of accidents in smaller groups of industrial employees. Thus studies on accidents in relation to the influence of fatigue, illumination, speed of production, working shift, etc. have been discussed at length,[1] and the results of a number of studies[2–6] on age, experience and accident liability in relation to place of work, occupation, time and nature of injury have been reported.

The present paper discusses two investigations into injuries sustained by Bantu mineworkers underground, one into first aid injuries on a gold mine, and the other into hospitalizations on seven other gold mines. The aims were, firstly, to obtain factual data regarding frequency, times and sources of accidents, the personnel involved, their ages and experiences, and the nature of their injuries, in order to provide a basis for improving preventive measures wherever possible and, secondly, to determine whether the incidence of minor injuries could be used as a valid criterion in the prediction and control of more serious injuries, and, thirdly, to determine, if possible, whether the tendency among mine safety personnel to consider only more serious injuries for study is justifiable.

METHOD

The data on first-aid injuries were collected by three clerks, each in a shaft station and under the supervision of a mine safety officer. For over six months information on injuries was obtained from the injured Bantu when they reported at the local dressing station. The additional data relating to the injured, such as age, experience and the distribution of underground populations were extracted from the mine records. The information on hospital cases was obtained from a central hospital which for some years has had an established system of records on hospitalizations on computer cards. The most recent information for one complete year was selected for study. The analyses consisted in defining the injury distributions for the variables under study and the injury rates for groups of the population at risk. Cross-analyses between variables were performed and tested for significant differences from the expected population frequencies. A total of 3 086 first aid injuries and 4 252 hospital cases were analysed.

RESULTS

Job categories

The distribution of injuries according to locality was found to be determined largely by the degree of activity and labour concentrations in the different working places. Seventy per cent of the injuries occurred in production stopes, 17 per cent in development areas and 13 per cent in places such as haulages, shafts and stations. Drilling crews (drillers and their assistants comprising between 15 to 20 per cent of the underground population) whose activities are confined solely to stope faces and developing ends accounted for 30 to 37 per cent of the injuries recorded in each of the eight mines.

The injuries sustained by these workers plus stope teams (the function of the latter being to install and remove support, build blasting barricades, and to scale and clear rock) contributed 49 per cent and 58 per cent of the total first aid and hospital cases, respectively. The high incidence of injuries to these workers parallels that of injuries to machinemen and packers in coal mines[6] whose job functions and activities are very similar. The pattern would therefore appear to be characteristic of mines with narrow seams.

In Table I, the injury rates of these job categories are shown together with those of other job categories with high injury rates, but which engage a smaller proportion of the underground labour force. The high rate of hospitalizations compared with first aid cases for locomotive drivers and guards may be related to the inherent hazards of these jobs which make them more susceptible to injury to the legs, trunk and head. In both studies injuries to these parts were found to be significantly higher ($p = 1$ per cent) which may explain the discrepancy between these rates. Moreover, the lengths of time spent in hospital by these labourers in terms of average shifts lost were among the longest.

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TABLE I

INJURY RATES, FREQUENCIES AND PERCENTAGES FOR JOB CATEGORIES

	FIRST AIDS (DISTRICT A)			HOSPITALIZATIONS (DISTRICT B)																	
	MINE 1			MINE 2			MINE 3			MINE 4*		MINE 5*		MINE 6*		MINE 7*		MINE 8*		TOTAL (2-8)	
JOB CATEGORY	Rate/ 100/ Month	N	%	Rate/ 100/ Year	N	%	Rate/ 100/ Year	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Drilling crews	16.8	930	30.1	19.0	311	35.8	16.7	186	29.6	191	36.9	364	35.6	185	31.8	62	29.7	126	29.7	1425	33.5
Stope teams	14.6	581	18.8	10.4	216	24.9	9.4	173	27.5	110	21.2	259	25.3	159	27.3	47	22.5	96	22.6	1060	24.9
Winch drivers	11.6	312	10.1	10.3	88	10.2	10.6	51	8.2	42	8.1	88	8.6	34	5.8	11	5.3	27	6.4	341	8.0
Boss-boys (stope and development)	11.3	110	3.6	12.7	47	5.4	18.3	46	7.3	37	7.1	56	5.5	39	6.7	10	4.8	23	5.4	258	6.1
Loco guards	7.4	62	2.0	14.7	34	3.9	13.0	22	3.5	16	3.1	26	2.5	21	3.6	9	4.3	7	1.7	135	3.2
Loco drivers	5.2	52	1.7	10.9	25	2.9	16.4	27	4.3	21	4.1	37	3.6	15	2.6	7	3.3	39	9.2	171	4.0
All other Labour	4.2	1039	33.7	4.5	147	16.9	3.1	123	19.6	101	19.5	193	18.9	129	22.2	63	30.1	106	25.0	862	20.3
TOTAL MINE	7.7	3086	100	9.6	868	100	7.6	628	100	518	100	1023	100	582	100	209	100	424	100	4252	100

*LABOUR COMPLEMENTS TO CALCULATE ACCIDENT RATES ON THESE MINES WERE UNAVAILABLE

The main source of injuries was falls of ground which caused half of the first aid cases and a third of the hospitalizations. Drilling crews, mostly during drilling operations, sustained more injuries from this source than other workers, namely, 65 per cent and 45 per cent for first aid and hospital cases, respectively. In an analysis of the effect of job experience upon injuries from falls of ground it was found that the injury rates were higher for this source than for any other in the case of labourers with minimal job experience. By the sixth and eighth month of experience, however, these rates for falls of ground had decreased substantially to a level lower than that for other sources. These differences were significant ($p = 5$ per cent) and suggest that labourers had to gain underground experience before they could learn to recognise this hazard effectively, an ability which surface training alone would not provide adequately.

Age and experience

Research into the relationship between accidents, experience and age have shown that the accident rate is highest among the less experienced and younger employees. Some attempts have been made[4,5] to determine the relative influence of experience and age on accidents by minimizing the effect of one of the variables. A higher correlation of accidents with age than with experience has been reported by these investigations. The present results, however, do not support these earlier findings: the differences between injury rates were not as pronounced for age as for experience. Furthermore, first aid injury rates tended to increase among the higher age groups. Similar findings[7] have been interpreted to be the result of poorer perceptual and motor performances of older workers compared with those of young workers and to fatigue[1] arising from the arduousness of underground work which is thought to affect older workers more. From this it appears that the role of age as a determinant of liability to injury compared with experience is confounded by extraneous factors which render it of less practical importance in the mining situation. Although it is conceded that mining experience (overall length of service in the mining industry) and age are related ($r = 0.61$, $p < 0.001$) and their relative influence difficult to determine, the same relationship did not hold true between job experience (length of service in a specific job as from the beginning of the existing contract) and age in the cases studied ($r = 0.10, p < 0.10$).

Job experience, however, showed a strong influence on liability to injury which can be more definitely ascribed to lack of familiarity with the particular job than to immaturity in age. Furthermore, the decrease in accident rates with increase in experience has been attributed to some extent to a natural selection process which results in the weeding-out of workers who have been found to be either unfit for the job or incapable of continuing work after a severe accident. The fact that a comparable reduction in the incidence of both minor injuries and hospitalizations was associated in these studies with increase in experience suggests that this is not an important consideration. It is unlikely that the large number of workers sustaining minor injuries such as cuts, abrasions, and so on, would be affected to any significant extent by such a process of selection to make the influence of experience on accident liability any less relevant.

Fig. 1 displays a cross-analysis of the combined effects of mining experience and job experience performed on a sample of minor injuries ($N = 986$) to drilling crews and stope teams. Labourers within the first few months of job experience showed in every instance higher injury rates than labourers with longer job experience, irrespective of the overall length of service in the mining industry. The three tallest columns in the figure represent approximately 15 per cent of the underground workers whose experience do not exceed four months on the particular job and two-and-a-half years of service in the mines. Such a grouping of men would provide a useful basis for closer supervision and follow-up training by differentiating distinctly between experienced and inexperienced men. It is not sufficient that a supervisor should be familiar with the less experienced labourers in his own gang. These men should be made easily recognizable by means such as a luminous band on their helmets so that there would be no difficulty in identifying the inexperienced worker underground at any time. This would facilitate a supervisor's task by narrowing his field of interest to those, as a group, most likely to be involved in accidents. It would provide training officers with a readily available sample for the evaluation and improvement of existing training procedures. It would also provide a check on the extent to which safety practices taught during training are adhered to under the stress of operating conditions in the initial critical period of adaptation to underground work.

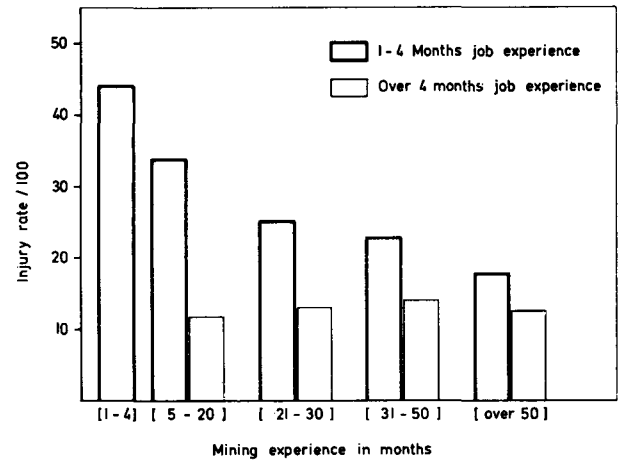

Fig. 1—Cross analysis between mining experience and two levels of job experience.

These results serve to lay stress, in any potentially dangerous occupation, on the importance of making special efforts to give special attention to the less experienced worker. Labourers starting on a new contract are more susceptible to injuries due to a lack of the required skills and to inadequate fmiliarity with the methods of a new job, which are only partially acquired after lengthy experience on other occupations in the mine. The reappointment, transfer or promotion of a labourer to the same or related job would thus be a practice worth adopting, wherever possible, as this would be likely to bring about a reduction in liability to injury and an increase in job efficiency. This is particularly important in the South African gold mining industry as the migratory nature of the Bantu labour force and the short length of contracts and training time make the immediate attainment of an acceptable degree of job proficiency desirable.

Time of accidents

The hourly incidence of injuries for the morning shift is shown in Fig. 2. This shift alone accounted for over

three-quarters of the recorded injuries. An increase in the injury frequencies towards a peak hour (10-11 a.m.) and a subsequent decrease towards 2 p.m. was found to be closely associated with the hourly average compressed air readings at the shafts. As the number of operating drills increases the pressure decreases correspondingly which is an indication of the drilling activity in the mine. Studies with munition workers[1] have shown a considerable qualitative resemblance between the accident and output curves of the factory workers, and this phenomenon has been ascribed to the probable influence that small increases in hourly output may have on injury frequencies. The hourly increase in injuries in the present studies was spread across all job categories and it is likely that the increased injury frequencies were related to increased output and production pressure. This is complicated, however, by other factors such as the pattern of work activities throughout the shift. In the early period of the shift greater precautionary measures are taken while making the working place safe. Once this is done, a slackening of supervision may ensue and labourers are left on their own to a greater degree for the intermediate period. The alertness of labourers may similarly decrease as the shift proceeds. Conditions of light, heat, ventilation, noise and operational congestion in stopes may also add to the discomfort, efficiency loss, fatigue and mental inertia of labourers. These factors undoubtedly contribute towards a rise in the number of accidents but are at present largely intangible and difficult to combat effectively.

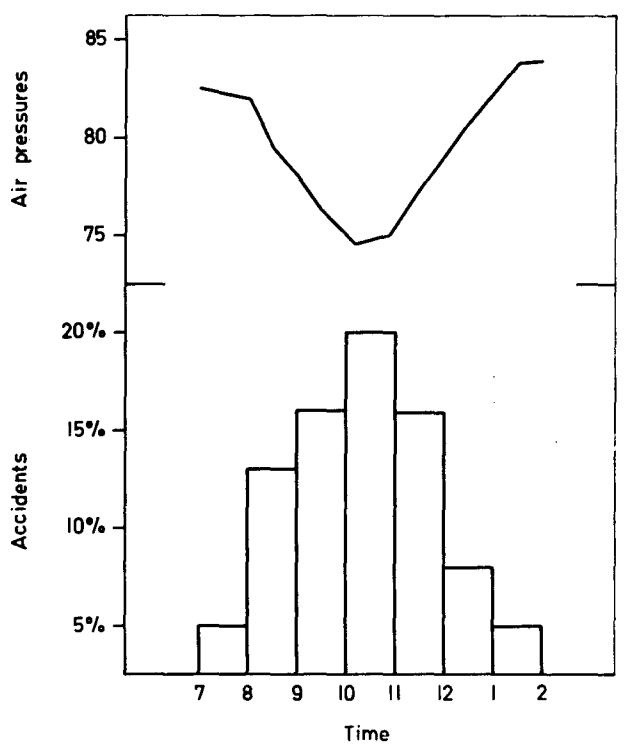

Fig. 2—Hourly distribution of accidents and air pressures in lb/in.²

Minor injuries and hospitalizations

The hypothesis framed on *a priori* grounds that minor injuries are a reliable predictor of more serious ones has, in fact, been supported by the results of the above studies. The relationships that could not be clearly established were the result of differences in classification procedures inherent in each study. These studies had initially been planned and carried out independently so that only in the final analysis were they combined. For instance, Table II shows the distribution of injuries to parts of the body for both studies. The high proportion of hospitalized leg injury cases arises from the fact that seriousness of injury is not reflected adequately by the percentage of cases of any one type which is hospitalized. For example, a man with a hand injury would often be placed on convalescent light duty and be exempt from being classed as a hospital case, whereas another with an injury of equal severity to the leg would have to be admitted to a hospital bed. This is further supported by the fact that men with leg injuries remained in hospital twice as long on the average as those with hand and arm injuries.

TABLE II

PERCENTAGE INJURY DISTRIBUTION FOR PARTS OF THE BODY

	HANDS	ARMS	LEGS	HEAD	TRUNK	MULTIPLE
First Aid Injuries	58	21	9	7	3	2
Hospitalizations	29	15	32	13	10	1

Although the eight mines on which the study was made were members of the same mining group, the study was complicated further by the fact that the two sets of data relating to minor injuries and hospitalizations were obtained from mines in two different districts. Nevertheless, data obtained from the Mines Department for two consecutive years indicated that the rates of reportable and fatal accidents in each of the two districts were comparable. Table III shows that in only one major category, namely, accidents caused by falling material, was the accident rate consistently lower ($p < 0.02$) in district A ($N = 6$, including the one mine studied) for those two years than the accident rate in this category for the seven mines in district B. In fact, the variation in accident rates between districts was not significantly different from the variation found within each district during those two years.

This finding does not agree with the widely-held belief that differences outweigh similarities in underground conditions in mines to the extent of rendering any comparison between mines pointless. It appears from this that the opposite is more likely to be true and that greater co-operation by safety departments in exchanging information regarding accidents in mines, districts or groups would greatly increase knowledge of accident patterns in the industry. From an accident prevention point of view it can be argued that, generally, data on fatal accidents are a valuable source of information only on an industry basis, data on hospitalizations on a district or group basis and data on minor injuries on an individual mine basis. Depending on the completeness and accuracy of the records, data on minor injuries have the advantage over those on serious ones of providing in a short time an updated sample which may be regarded as representative of the accident pattern on a mine at that time. This makes the study of minor accidents extremely valuable from the viewpoint of accident control. Hospitalizations, especially fatalities, are

TABLE III

COMPARISON OF UNDERGROUND ACCIDENT RATES BETWEEN TWO DISTRICTS

(REPORTABLES AND FATALITIES)

CATEGORY	YEAR I		YEAR II	
	DISTRICT A (N=6)	DISTRICT B (N=7)	DISTRICT A (N=6)	DISTRICT B (N=7)
Fall of ground	21.1	23.4	23.4	21.3
	$p > 0.40$		$p > 0.40$	
Trucks and tramways	12.7	16.0	12.5	12.8
	$p > 0.20$		$p > 0.80$	
Falling material	8.0	14.6	10.1	14.1
	$p < 0.01$		$p < 0.02$	
Slipping and falling	4.2	5.9	4.9	4.5
	$p < 0.05$		$p > 0.60$	
All categories	66.6	81.8	77.2	74.4
	$p > 0.05$		$p > 0.10$	

too infrequent on a mine to be of great assistance to a manager in deciding on a course of action such as the formulation and evaluation of accident prevention programmes because, statistically, the degree of confidence attached to an estimate based on a sample is related closely to the size of the sample.

CONCLUSION

The problems encountered in supervising large labour gangs underground necessitate the development of a differentiated programme of accident prevention in line with the actual pattern of accidents. In this way selective attention can be given to specific types of hazards such as those to which inexperienced men and specific job categories are exposed and which require special vigilance by line supervisors and close attention in the design of training programmes. Thus, in the absence of more sophisticated and costly research procedures, mine safety departments may provide themselves with concrete data as guides in the assessment of priorities in accident prevention.

Mining personnel, although to some extent acquainted with the above findings, lack the factual and precise information which would make accident prevention a concrete concept. Full realization of the facts concerning accidents is a basic requirement for attaining greater uniformity of effort, practice and attitude in the approach of industrial personnel to the problem of safety. From the results of a multiple-choice questionnaire administered to production personnel ($N = 104$), the scores of these men were found on average only slightly superior to those which would have been obtained by chance. For instance, only half of the sample considered that the accident rates sustained by drilling crews exceeded the average on the mine. Thus it is likely that the effectiveness of supervision is affected adversely by the lack of factual knowledge. This lack may explain the limited success of preventive and supervisory practices as laid down in programmes which are often too general while the propaganda is too abstract.

Following the leads provided by other researchers,[8,9,10] an attempt has been made in these investigations to establish the value of minor injuries as a reliable basis for designing programmes for accident prevention. The investigation of accidents in the gold mines of South Africa is confined largely to hospitalizations and more specifically to fatalities which are subjected to intensive inquiry. The study of minor accidents is largely neglected or pursued with little enthusiasm by mine safety personnel. This is mainly the outcome of a failure to appreciate that the study of minor accidents is frequently easier and quicker, when the objective is to pin-point and eliminate sources of accidents without regard to the question of responsibility. Safety programmes may thus be pursued at considerable cost to a mine and promising ones discontinued on the basis of inconclusive findings obtained from the evidence of hospital cases, especially fatal cases which, by virtue of their comparative rarity, require a longer time before their frequencies can be evaluated with confidence.

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