Minerals Council South Africa

MEMORANDUM

SUBJECT: CHAMBER OF MINES OF SOUTH AFRICA – CERTIFICATE IN MINE ENVIRONMENTAL CONTROL – OCCUPATIONAL HYGIENE PAPER 5	**EXAMINER: Ms. S Wheeler**
SUBJECT CODE: COMMEC5	**MODERATOR: Prof C Badenhorst**
EXAMINATION DATE: 15 OCTOBER 2018	**TOTAL MARKS:** [100]
TIME: 14:30 – 17:30	**PASS MARK:** (60%)

NUMBER OF PAGES: 17

SPECIAL REQUIREMENTS:

THIS IS NOT AN **OPEN BOOK EXAMINATION**. FORMULA HANDOUT IS AVAILABLE

INSTRUCTIONS TO CANDIDATES:

1. Answer all questions **legibly** in English.
2. Write your **ID number** on the outside cover of each book used and on any graph paper or other loose sheets handed in.

NB: Your name **must not** appear on any answer book or loose sheets.

3. Show all calculations **and check calculations on which the answers are based.**
4. Hand-held electronic calculators may be used for calculations.
5. Write **legibly** in ink on the **right hand page** only – **left hand pages will not be marked**.
6. Illustrate your answers by means of sketches or diagrams wherever possible.
7. Answers must be given to an accuracy which is typical of practical conditions.

   NB Ensure that the correct unit of measure (SI unit) are recorded as marks will be deducted from answers if the incorrect unit is used. (even if the calculated value is correct).
8. In answering the questions, full advantage should be taken of your practical experience as well as data given.
9. Please note that you are not allowed to contact your examiner or moderator regarding this examination.
10. Cell phones are **NOT** allowed in the examination room.

QUESTION 1

1.1 Welding fumes consist of mixtures of airborne gases and fine particles which if inhaled or swallowed may result in risks to health. The degree of risk will depend on: the composition of the fume, the quantity of fume in the air which is breathed and the duration of exposure. List and discuss the main health effects associated with excessive exposure to welding fumes.

(4)

Irritation of the Respiratory Tract: *Gases or fine particles of fume can cause dryness of the throat, tickling, coughing, tightness of the chest and difficulty in breathing.*

Metal Fume Fever: *The inhalation of many freshly formed metallic oxides, such as those of zinc, cadmium, copper etc may lead to acute flu-like illness termed metal fume fever. With the exception of exposure to cadmium fume serious complications are rare. The commonest cause of metal fume fever occurs from welding galvanised steel.*

Systemic Poisoning: *This can result from the inhalation or swallowing of substances contained in welding fume such as fluorides, manganese, lead, barium and cadmium. The presence of these substances in the fume depends upon the welding process being used and the material being welded.*

Long Term or Chronic Effects: *The inhalation of welding fumes can lead to the development of benign X-ray changes, referred to as Siderosis. A subject of current concern is whether welders have an increased risk of developing cancer as certain constituents of some welding fumes, such as hexavalent chromium and nickel may be carcinogenic.*

1.2 List ten (10) aspects that should be included in a report on occupational exposure assessment.

(5)

(any 10, half mark each)

- *The name of the person (s) or institutions undertaking the assessment and the measurements*
- *The name of the substances considered*
- *Name and address of company / mine*
- *The description of the workplace factors including working conditions during measurements.*
- *The purpose of the measurement procedure*
- *The measuring procedure*
- *The time schedule (date, beginning and end of sampling)*

- *The occupational exposure concentrations*
- *All events or factors liable to influence appreciably results*
- *Details of the quality assurance, if any*
    - *Environmental conditions at the time of the measurements*
    - *Any limitations*
    - *PPE used by the person at the time of the measurement*
    - *Results of the comparison with the limit value*
    - *The Observer's name*
    - *The type and serial number of the equipment used*

1.3 List and briefly discuss the 7 steps that should be addressed in a Code of Practice pertaining to the "**Determination of HEGs**", as stipulated in the **new** Guideline for the Compilation of a Mandatory Code of Practice: Occupational Health Programme on Personal Exposure to Airborne Pollutants.

(14)

HEGs should be identified for purposes of personal exposure monitoring. The baseline risk assessment will enable the identification of HEGs, which will be established as follows:

Step 1

The sub-division of the mine into sampling areas (e.g. surface = sampling areas 1, underground section A = sampling area 2, underground section B = sampling area 3, underground section C = sampling area 4, etc.).

Note: *Surface operations proceed to step 3. Underground operations proceed to step 2.*

Step 2

At underground mines, sampling areas should be sub-divided into ventilation districts which are areas of a mine, ventilated independently from other areas with a common dedicated intake and return airways. Any airborne contaminants released in a ventilation district will only affect that particular district and does not circulate through other areas of the mine where people may be exposed.

In order for an area to be classified as a ventilation district it must comply with:

- *Ventilated independently from other areas.*

- *Independent intake and return airways.*
- *Does not contaminate other areas.*

<u>Step 3</u>

The sub-division of the sampling areas into activity areas as per the activity area code list found in Annexure A (mandatory codes). Annexure A must be complied with.

<u>Step 4</u>

To ensure that adequate measurements of personal exposures are taken in line with the identified airborne pollutants for each activity area. If sufficient historical person exposure data is not available regarding the extent of the risk, a personal monitoring survey must be undertaken for each identified airborne pollutant.

<u>Step 5</u>

A statistical analysis should be conducted. The results od the identified airborne pollutants present, either from historical data or from measured data, during the personal sampling strategy, in that particular activity area should be compared to their respective OEL values. Plot past data over time to determine whether the exposure trends are higher or lower. If the exposure trends exist, the Section 12(1) appointee should use only the most recent exposure data in the initial assessment.

In order to ensure that HEGs are correctly allocated a statistical analysis of the results is to be done.

Once the personal exposures within each activity area have been compared to their respective OEL values, each activity area can now be categorised into the classification bands to determine the various HEGs within that activity area. The classification bands for airborne pollutants.

<u>Step 6</u>

In this step where a single pollutant acting independently has been identified in an activity are the following process must be followed:-

a) *Once the personal exposures within each activity area has been compared to the respective OEL values of the single pollutant, that activity area can now be categorised into classification bands determined by the various HEGs within the activity area.*

b) *If an employee is exposed to a number of identified pollutantsm which have an additive effect, step 7 must be followed.*

c) *Repeat step 5 for every such identified pollutant.*

<u>Step 7</u>

Where pollutants that have an additive effect have been identified in an activity area where these effects are additive, their combined effects must be used when classifying the activity areas into their respective HEGs. The following formula must be used to assess the combined effect.

C1/L1 + C2/L2 + C3/L3… for compliance, the combined effect should be <1

Where C1, C2 etc. are the concentrations of the constituents in air

And L1, L2 etc. are the corresponding OELs.

1.4 Name two analytical methods commonly used in South Africa to identify and quantify the crystalline silica content of a collected respirable dust sample.

(2)

X-ray diffraction (XRD)

Infra-red (IR)

[25]

QUESTION 2

2.1 The following exposure data was collected for a specific HEG. Using the statistical method described in the new Guideline for an Occupational Health Programme on Personal Exposure to Airborne Pollutants, determine whether the HEG is statistically correctly defined. Interpret your results. (10)

Exposure Data (HEG A)
0.89
1.32
1.78
1.87
1.51
1.45

Descriptive Statistics	
Mean	1.47
Standard error	0.14
Median	1.48
Mode	N/A
Standard deviation	0.35
Sample variance	0.12
Kurtosis	0.57
Skewness	-0.72
Range	0.98
Minimum	0.89
Maximum	1.87
Sum	8.82
Count	6
Confidence level (95%	0.36

Calculations required		
2 X SD	=	0.702
Mean – 2SD	=	0.767

Mean + 2SD	=	2.172
90^{th} Percentile	=	1.825

Interpretation

From the above it can already be estimated that this HEG is statistically correctly defined.

a) *More than 5 samples were taken*

b) *As the mean value (1.47) falls within the "B" Category and the 90^{th} percentile value (1.825) also falls within the "B" Category.*

c) *95% of the samples must be between mean – 2SD (0.767) and mean + 2SD (2.173). From "Data" 0 samples <mean-2SD > mean + 2SD*

d) *0/6 = 0%*

2.2 List five consequences associated with shift work (5)

- *Shift workers generally have more digestive and nervous system disorders*
- *Nightshift workers more often misuse drugs*
- *Nightshift workers more often suffer from chronic fatigue, and*
- *They tend to have poor eating habits.*
- *In terms of occupational sickness, they more often exhibit symptoms of weariness, mental irritability, depression, loss of vitality and disinclination to work.*
- *Psychosomatic disorders also show increased risk in the form of loss of appetite, sleep disturbances, digestive problems and stomach and duodenal ulcers.*

(Any five)

2.3 Briefly discuss and give examples of the two basic types of hearing loss. (6)

Conducive hearing loss:

- *Caused by disorders of the outer or middle ear,*
- *Prevents sound energy from reaching the inner ear.*
- *Caused by excessive wax in the auditory canal, or*
- *By an explosion which may damage the eardrum.*
- *Most hearing impediments of this type are correctable.*

Perceptive hearing loss:

- *Caused by disorders of the inner ear or the auditory nerve.*
- *Brief exposure to excessive noise produces a temporary hearing loss, but*
- *Repeated or prolonged exposure produces permanent hearing loss of the perceptive type,*
- *Cannot be cured and affects the ability to communicate properly.*

2.4 Describe the key objectives of industrial audiometry. (4)

- *To establish quantitatively the hearing status of an individual and to monitor hearing during the period of employment in order to control the risk of occupational hearing loss.*
- *Industrial audiometry also provides the ultimate test of success of a hearing conservation programme in that it demonstrates the benefit of personal hearing protection in maintain hearing acuity.*

[25]

QUESTION 3

3.1 Define the following terms

(5)

3.1.1 Raynaud's symptoms

Is a vibration syndrome which results from insufficient blood supply to the fingers. These turn white, go numb and sensation and control over fingers are lost. Also known as "white finger disease"

3.1.2 Physiology

The study of the physical and chemical processed that take place in living organisms during the performance of life functions.

3.1.3 Visual Acuity

The inability of the eye to see very small objects.

3.1.4 Sensitisers

Results in the skin becoming sensitive to dermatosis even from low level exposures. This usually develops after repeated exposures over a long period of time.

3.1.5 Ionising radiation

Is electromagnetic (X-ray and gamma) or particulate (alpha, beta) radiation capable of producing ions or charged particles with enough energy so that during an interaction with an atom, it can remove tightly bound electrons from their orbits, causing the atom to become charged or ionised.

3.2 Briefly discuss exposure to radiation associated with underground mining activities under the following headings:

a) Short–lived alpha emitting radionuclides
b) Long–lived alpha emitting radionuclides.

(8)

Short – lived alpha emitting radionuclides
Radon and radon daughters

The noble gas Rn222 produced by decay of Ra226 in ore bodies, migrates through rock and emanates continuously from mine surfaces into all air spaces.

After emanation, it is carried along in ventilation currents and produces the solid decay products Po 218, Pb 214, Bi 214 and Po 214 (RaA, RaB, RaC and RaC’).

Being a noble gas, radon itself remains in mine air until air is discharged above ground. Because of its relatively long half-life (3,82 days) compared with the residence time of air in a mine, radon concentration increase in proportion to its rate of emanation and to its travel time along different mine passages. By contrast Po 218 has a half-life of only 3,05 min and thus builds up rapidly with time, giving rise to its immediate decay products, all of which have fairly short lives (Pb 214: 26,8 min; Bi 214: 19,9 min; Po 214: 2,74 x 10 min). After formation, Po 218 exists briefly in atomic form, before becoming attached to aerosol particles or solid surfaces.

In aerosol form, the radon decay products tend to remain suspended, although they are subject to electrostatic, inertial and diffusive forces by which they can be removed from mine air. In any case, activity concentrations of these radon decay products increase rapidly with increasing residence time of the air in the mine, The factors which contribute further to the variability in concentration of these radionuclides are changes in radon emanation rate into mine spaces brought about by alterations in the differential air pressure (both naturally and mechanically induced), changes in ventilation rate and variations in mining activity. Consequently, the relative composition and concentration of the mixture of radon decay products at any given location can only be determined by measurement.

Even in a mine under adequate control, the concentration of radon decay products may vary considerably within the mine, from that of ambient air at the point where fresh air is drawn into the mine, to high levels in exhaust air. This must be taken into account in monitoring and control.

1) Thoron and Thoron daughters

It is recognized that Rn 220 exhalation from rock is also a source of radiation exposure; Rn 220 (also called throron) is a decay product of Th 232. The physical properties of Rn 220 and its decay product, and consequently their behaviour in mines, are almost the same as those of Rn 222 and its decay products. However, when the masses of uranium and thorium per unit mass of rock are similar, the relative importance of Rn 220 is expected to be less than that of Rn 222, since its half-life is only of the order of one minute, and also *because the specific activity of Th 232 in ore bodies is less than that of U. 238 However, in some mines, high concentrations of thorium are present and, in these circumstances, exposure to Rn 220 and its decay products may be predominant.*

(b) Long-lived Alpha Emitting Radionuclides

Dusts containing nuclides of the uranium and thorium decay series, are dispersed directly from mining and processing operations and may be resuspended from surfaces by rapid air currents and physical disturbances. These dusts may be encountered in all mining and processing operations underground and on surface.

The long-lived alpha emitting radionuclides in the uranium decay chain are uranium 238, uranium 234, thorium 230, radium 226, lead 210 and polonium 210, and in the thorium decay chain thorium 232, thorium 228 and radium 224.

3.3 Discuss the effects of radiation on the human body under the following headings

(a) Physiological effects

(b) Biological effects

(8)

PHYSIOLOGICAL EFFECTS OF RADIATION EXPOSURE

Penetrating Powers of Radiation

The alpha particle is a massive particle (compared to a beta particle) and travels relatively slowly through matter. It thus has a high chance of interacting with atoms along its path and it will give up some of its energy during each of these interactions.

As a consequence, alpha particles lose their energy very rapidly and only travel very short distances in dense media.

Alpha particles can scarcely penetrate the dead outer layer of the skin, but they are harmful when inhaled or ingested, or as a result of a wound becoming contaminated.

Beta particles are very much smaller than alpha particles and travel much faster. Thus, they undergo fewer interactions per unit length of track and so give up energy more slowly than alpha particles. This means that beta particles travel further in dense material than alphas.

Beta particles may travel up to 5 metres in air and about 1 cm into tissue. This type of radiation is not hazardous to internal organs when irradiated from outside the body. When inhaled or ingested they could be hazardous to internal organs.

Gamma radiation loses its energy mainly by interacting with atomic electrons. It travels very large distances through air and dense media and can pass right through the body. It is very difficult to absorb completely and is hazardous to people whether irradiated from the outside of the body or through ingestion/inhalation of radioactive materials.

Radiation and Tissue

When radiation passes through matter, including tissue, it loses energy. Alpha and beta particles, being charged, lose energy in electrical interactions with the atomic electrons near which they pass.

Gamma and x-rays transfer energy in a variety of ways, but each involves the liberation of electrons, which then lose energy in electrical interactions. During such electrical interactions, an electron may be ejected from an atom in a molecule, thus leaving the molecule positively charged.

The process by which a neutral atom or molecule becomes charged is called ionisation and the resulting entity an ion. An ejected electron may, in turn, ionise other atoms or molecules.

The passage of a charged particle through atoms may also impart energy to the atomic electrons without actually ionising them. This process is called excitation. All energy imparted to tissue by radiation is eventually dissipated as heat.

The basic unit of tissue is the cell. Each cell has a nucleus, which may be regarded as its control centre. Of particular importance is the compound deoxyribonucleic acid, DNA, found mainly in the nucleus of the cell. The DNA controls the structure and function of the cell and passes on copies of itself. These molecules are large and the structures which carry them, chromosomes, can be seen under a microscope. A DNA molecule may become ionised, resulting directly in chemical change which may find expression as a harmful biological effect, due either to highly localised damage or gross chromosome damage. Both kinds of damage have been implicated in inherited genetic defects and in the development of cancer.

BIOLOGICAL EFFECTS OF RADIATION EXPOSURE

Biological effects can be classified into somatic effects where the radiation exposure directly affects the individual during his life and genetic effects (hereditary) where the exposed individual's offspring are affected e.g. as a result of mutations.

Somatic effects can be divided into early (e.g. skinburn) and late effects (e.g. cancer). Early effects normally arise within a few hours or days depending upon the dose received. Early effects require quite significant doses e.g. in the order of at least 1 Sv or more to manifest themselves; if the dose is high enough e.g. 5 Sv or more death can result within days or weeks.

LATE EFFECTS

Late effects are the predominant effects resulting from radiation in the mining industry.

Malignant Diseases

The most important late effect of radiation is cancer (stochastic effect), which is always serious and often fatal. Each exposed person has an extra probability of contracting it, and that probability depends largely on the dose received. Increased cancer rates have been observed in individuals exposed to radiation. The situation is similar to smoking, where those who smoke most, run the highest risk of lung cancer, but by no means will all of them contract it.

Hereditary Defects

An important late effect of radiation is genetic damage, leading to hereditary defects, the probability but not the severity of which depends on dose.

The damage arises through irradiation of the gonads. Ionising radiation induces mutations, which are usually harmful in sperm and egg cells, or their precursors. The hereditary defects, caused by a change in the DNA, could range from the serious, such as mental retardation, to the trivial, such as skin blemishes.

Other Late Effects

There is a category of late effects that does not involve an element of probability: such an effect will appear in most individuals if a large enough dose equivalent is received, and the severity will increase with increasing dose. These are referred to as deterministic effects.

These effects are not ordinarily fatal, but they can be disabling or distressing. The function of some parts of the body may be impaired or other non-malignant changes may be induced. The best-known examples are cataracts (opacity of the lens of the eye) and skin damage.

High cumulative dose equivalents accrued over extended periods are normally required to bring them about.

Dose-Risk Relationships

At present there is no sound basis for assuming that there is any threshold of dose below which neither cancer nor hereditary defects can be caused by radiation.

Any dose of radiation is, therefore, presumed to produce some additional risk of these effects. For deterministic effects, a safe threshold of dose can be defined, below which the effect simply does not occur.

Irradiation during Pregnancy

Mention should be made of the risks to unborn foetus irradiated in the womb.

Should an embryo or foetus be exposed to radiation, developmental defects (reduction in the size of the head, mental retardation) may be induced if the exposure takes place at the time when the organs are formed.

Therefore, care should be taken to avoid subjecting pregnant women to x-ray examination involving the abdomen and there are special precautions and restrictions on the doses that fertile and pregnant women may receive if they are employed as radiation workers.

Conclusion

In summary, biological effects can be classified into two main categories:

Stochastic, and

Deterministic

Stochastic effect is when the probability of an effect occurring, rather than its' severity, is regarded as a function of dose, without a threshold e.g. cancer, genetic effects, etc.

Deterministic effect is where the severity of the effect can vary with the dose above the threshold where a definite dose threshold exists, e.g. cataracts of the lens of the eye, damage to blood vessels, infertility, etc. below which the effect does not occur.

3.4 List four underground areas where exposure to radiation is most likely to occur.

(4)

- *Areas where the ore body / reef is exposed*
- *Near dust producing operations eg. Tips, ore passess, handling of broke rock*
- *In poorly ventilated work places*
- *Where water laden with radon gas emerges from rock eg, fissure water*
- *Leakages of radon rich air from sealed areas into airways*
- *Areas where re-circulation of air takes place*
- *Fan drifts (gamma, surface contamination)*

[25]

QUESTION 4

A gravimetric dust sampling pump was issued to an underground employee in a gold mine. The dust pump operated for 520 minutes at a flow rate of 2.2l/s. The pollutant id crystalline silica quartz and was determined as 23.5% by means of a laboratory analysis. The gravimetric sampling analyst recorded the following information in the laboratory:

The average reference filter pre and post filter masses were as follows:-

Pre reference filter mass
20.01mg
19.98mg
20.17mg

Post reference filter mass
20.08mg
20.00mg
20.17mg

The pre weight sample filter mass was 20.15mg. whilst the post weight of the sample was 20.98mg. Determine the following:-

a) The corrected sample mass

Determine the average pre reference filter mass:

20.01 + 19.98 + 20.17 /3

= 60.16 / 3

=20.05mg

Determine post reference filter mass:

20.08 + 20.0 + 20.17 /3

=60.25 / 3

=20.08mg

Corrected mass: Post filter mass – Pre filter mass

20.08 – 20.05 = 0.03mg heavier and must be subtracted from the sample mass.

Sample mass = post weight – pre weight

= 20.98 – 20.15

= 0.83mg

Corrected sample mass:

= 0.83mg – 0.03mg

= 0.80mg

b) The sample concentration

Determine volume of air sampled:

2.2l/s x 520 = 1144l divide by 1000

= 1144 / 1000

= 1.144m³ of air.

Sample concentration = 0.80 / 1.144

= 0.699mg.m³

c) The TWA dust concentration

TWA = conc x (total sampling time (m) / 480)

0.699 x (520 / 480)

= 0.757mg/m³

d) The pollutant concentration

TWA conc x (% pollutant / 100)

0.757mg/m³ x (23.5 / 100)

= 0.177mg/m³

e) AQI

TWA conc / OEL

0.177 / 0.1

1.77

4.2 What will the calculated Air Quality Index be if a known concentration of $0.6mg/m^3$ insoluble nickel was measured in the same location.

(5)

- *AQI = Nickel concentration (mg/m^3) / OEL (mg/m^3)*
  - *= 0.9 / 0.5*
  - *= 1.8*
- *AQI = Nickel + Dust*
  - *= 1.8 + 1.77*
  - ***= 3.57***

4.3 State the current 8hr TWA OEL (as per the South African Mine Health and Safety Act and Regulations, Act 29 of 1996) for the following health stressors and give a typical example of sources of the stressors in the mining industry.

(5)

4.3.1 CO_2

4.3.2 Noise

4.3.3 CO

4.3.4 DPM

4.3.5 SiO_2

4.3.1 CO_2 - 5000ppm or $9000mg/m^3$ - Fires, blasting fumes, diesel machinery

4.3.2 Noise - 85 dB(A) - machinery

4.3.3 CO - 30ppm or $35mg/m^3$ - Blasting fumes, diesels, fires

4.3.4 DPM - No OEL in SA, use $0.16mg/m^3$ - Diesel equipment

4.3.5 SiO_2 - $0.1mg/m^3$ - Gold / coal bearing rock

[25]

TOTAL MARKS: [100]