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DEVELOPING INDICATORS FOR THE ASSESSMENT AND PROPER MANAGEMENT OF THE DIFFERENT LEVELS OF EXPOSURE TO POLYCYCLIC AROMATIC HYDROCARBONS (PAHs) GENERALLY ASSOCIATED WITH COKE-OVEN WORKERS

By

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STATEMENT OF OWN WORK

Declaration

I, Tianyuan Wang, declare that the contents of this thesis represent my own unaided work, and that the thesis has not previously been submitted for academic examination towards any qualification. Furthermore, it represents my own opinions and not necessarily those of the Cape Peninsula University of Technology.

Signed **Date** 04/02/2011

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ABSTRACT

Coke ovens may occur in the aluminium, steel, graphite, electrical, and construction industries. In the work area coke-oven workers may be exposed to various chemical compounds. Polycyclic aromatic hydrocarbons (PAHs), as human carcinogen, are primary compounds in coke oven emissions (COEs) generated in the coking process. Coke oven workers are often exposed to PAHs and can lead to a variety of human diseases.

The primary routes of potential human exposure to coke oven emissions are inhalation and dermal contact. Occupational exposure may occur during the production of coke from coal, or while using coke to extract metals from their ores to synthesize calcium carbide, or to manufacture graphite and electrodes. Workers at coking plants and coal tar production plants, as well as the residents surrounding these plants, have a high risk of possible exposure to coke oven emissions.

It is known that coke production could be carcinogenic to humans (Group-1) by IARC. There has been sufficient epidemiological evidence suggesting an etiological link between carcinogenic polycyclic aromatic hydrocarbon (PAHs) exposure and lung cancer risk among coke-oven workers. Lung cancer among coke-oven workers has been classified as one of the eight prescribed occupational cancers in China, and its incidence rate was about 10 times that of the general population. Therefore, lung cancer of coke-oven workers is still a critical issue in the field of prevention and control of occupational cancers in China.

This thesis explores the various exposure levels of workers to PAHs at a steel plant in China. The measurement will focus on the exposure difference of personal sampling among workers in selected job classifications given the job descriptions and the coking process. The Benxi Steel Industry in Liaoning province of China (BXSI) was selected as the research location. Liaoning province is in the North of China and the location of various heavy industries in China. The measurements will be done two separate coke ovens in Benxi Steel Industry. One new coke oven was built in the 90's last century (coke oven N) and the other older coke oven was

built in the 1940's in last century (coke oven O). In this research, the total number of employees that were selected in the sample for both coke ovens are 64 samples included 54 coke oven exposure workers and 10 non-exposure administrative workers working at the plants.

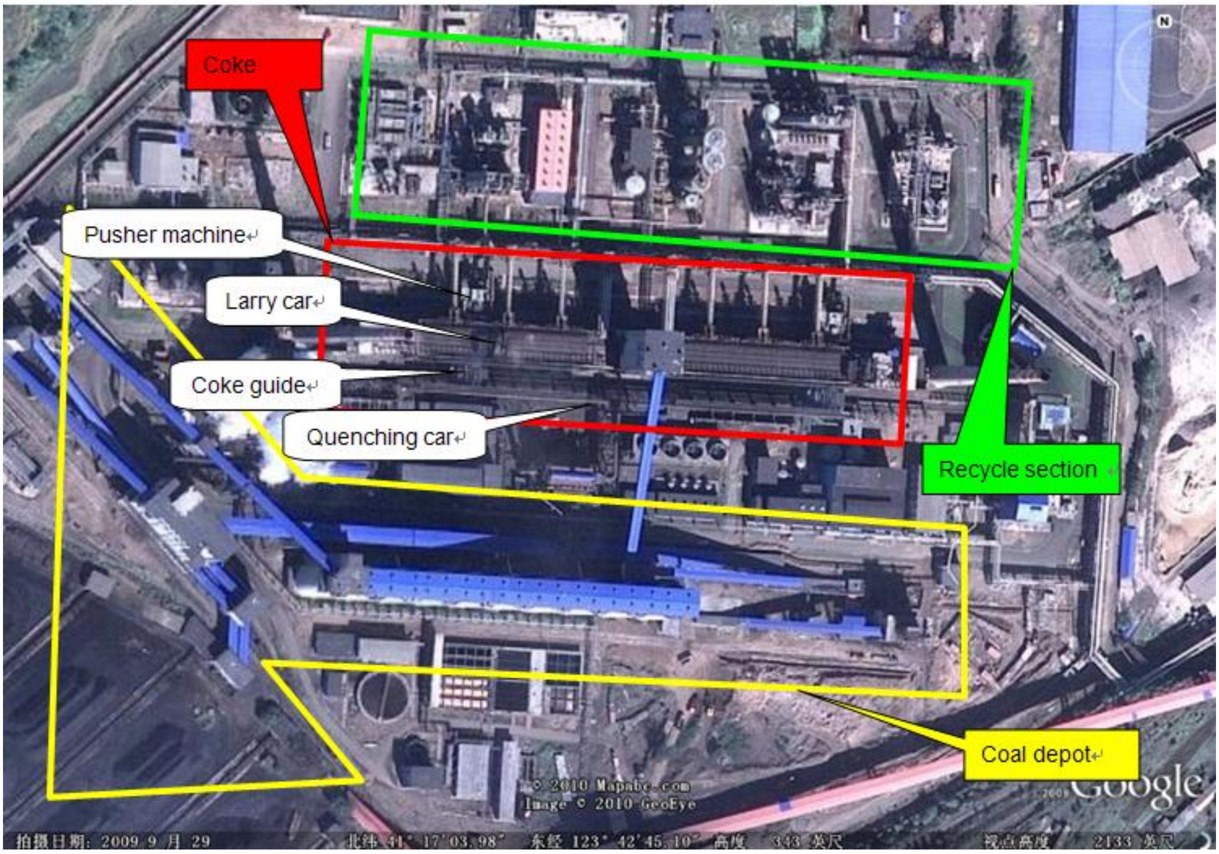

Figure 1.1 Coke oven sketch map

For the primary sampling, HAPSITE Smart man-portable, Agilent 6890N Network Gas Chromatograph was used in the coke-oven area to identify the organic compound in order to determine the PAHs category in the coke oven work area. For accurate sampling, personal sample collection has been done with sorbent tubes and a PTFE filter through which air is drawn with a personal air sampling pump. The sample was analysed in a laboratory equipped with an Agilent 6890N Network Gas Chromatograph.

The primary aim of the project was to obtain indicators of veracious PAHs exposure levels for coke oven workers in order to create a proper risk assessment protocol. A further aim of the project was to investigate the feasibility of designing a proper control management protocol to minimize exposure of coke oven workers to PAHs. It is envisaged that this will also provide the effective basic data for other future health control research projects.

GLOSSARY

Coke oven: A retort in which coke is produced by the destructive distillation or carbonisation of coal.

Coke oven battery: A structure containing a number of slot-type coke ovens.

Coke oven emissions (COE): The benzene-soluble fraction of total particulate matter present during the destructive distillation or carbonisation of coal for the production of coke.

Polycyclic aromatic hydrocarbons (PAHs): PAHs are a group of organic contaminants that form from the incomplete combustion of hydrocarbons, such as coal and gasoline. PAHs are an environmental concern because they are toxic to aquatic life and because several are suspected human carcinogens.

HAPSITE Smart: The only person-portable, gas chromatograph/mass spectrometer (GC/MS) that provides lab-quality data of identification and quantification of toxic industrial chemicals and chemical warfare agents.

Gas chromatograph/mass spectrometer (GC/MS): The benchmark for positive identification of organic chemicals with the highest degree of accuracy of any available analytical technique.

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CHAPTER 1

INTRODUCTION

The aim of this research was to evaluate the polycyclic aromatic hydrocarbons (PAHs) exposure levels among coke oven workers in the steel industry in China with reference to the different work positions at the coke-oven and specific job roles. The PAHs exposure levels difference between new and old coke ovens will also be discussed. The aim of this study is also to contribute to a sustainable control program for exposure to PAHs.

As a pollutant, PAHs compounds are of concern because some PAHs compounds can seriously harm human health and have been identified by previous researchers as carcinogenic, mutagenic, and teratogenic. PAHs occur in oil, coal, and tar deposits, and are produced as by-products of fuel burning. PAHs are also found in some foods. Previous studies have clearly shown that most food intake of PAHs comes from cereals, oils and fats and smaller intakes could come from vegetables and cooked meats (Larsson, B.K., Sahlberg, G.P., Eriksson, A.T., Busk, L.A. 1983: 867–873); (Agency for Toxic Substances and Disease Registry. 1996).

In this research, the focus is on coke oven workers exposure to PAHs which is present in coke oven emissions during the coke making process. The PAHs exposure level in the coke-oven work place can be affected by various factors, such as temperature, rain, snow, humidity, air pressure and wind. As a result, this research will focus on the personal exposure level to each work role in order to realise the difference in PAHs exposure levels associated with each worker station in the coke oven plant. The personal sampling method was decided upon as the data collection technique for the purposes of this research as it was considered to be a better indicator to evaluate individual PAHs exposure levels than the static environment air sampling technique.

The primary aim of the research is to complete a proper PAHs risk assessment for coke oven workers at a coke oven plant. A further aim is to investigate the most feasible method to reduce

PAHs exposure levels in order to protect workers from hazardous chemical exposure in coke oven plants.

Also, this research can produce information to support other relative investigations, in the fields such as health effect evaluation and health risk assessment.

1.1 Background to the research problem

The use of coke as a fuel was pioneered by the Chinese in the 11th century during the Song Dynasty (960–1279 AD). In Europe, it was introduced during the 17th century in England to replace wood that became scarce and expensive due to deforestation. Coal's fumes, particularly smoke and chemical compounds, disqualified it from many applications, including coking and iron smelting (McNeil & William, H. 1982: 12).

In 1970, there were more than 13,000 coke ovens at 64 plants with an estimated 10,000 coke oven workers that were potentially exposed to coke oven emissions in the US. This number was essentially unchanged by 1975, but had declined to 23 coke plants operating about 3,800 ovens in 1998 (U.S. EPA. 2001).

In recent years, the developed countries are forced by laws as well as the pressure from environmental protection groups to close some of the coke oven industries. The result of this was that the coke manufacture industries were transferred from the developed countries to the developing countries. According to statistics, China produced 177,750,000 tons of coke and takes up 45% of coke yield in the world in 2003, and has become the world's biggest coke production base. Up to 2004, China has more than 700 major coke industries, and more than 1900 small and medium coke industries. The annual output of China is estimated at 178,000,000 tons. Thus, it is clear that coke oven workers do form a proportional large group of the workforce in China. To identify hazards during the coke making process and to evaluate the exposure levels of workers are important to provide an effective control program to protect coke oven workers from negative health effects.

Today, coke is still used in many places. The coke making techniques have been ameliorated quite a lot, but the coke oven emissions still harm worker's health during the coke production process. All over the world various occupational health authorities work to provide proper protection to the workers in coke ovens.

Coke ovens occur in the steel industry and are composed of a coke oven battery, charging larry car, coke pusher, coke guide car, coal tower, as well as a quenching tower, quenching car and recycle system. The coke oven battery forms the main body of the coke oven. During the production of coke, the coke oven emissions are most hazardous to the coke oven workers. Coke oven emissions can have a detrimental effect on human health. Currently, most of the regulatory action is aimed at reducing possible cancerous endpoints. Coke oven emissions contain literally several thousand compounds, several of which are known carcinogens and/or co-carcinogens (including polycyclic organic matter from coal tar pitch volatiles, beta-naphthylamine, benzene, arsenic, beryllium, cadmium, chromate, lead, nickel sub sulphide, nitric oxide and sulphur dioxide) (U.S. EPA. 1984). Therefore, this study focused on the Polycyclic aromatic hydrocarbons (PAHs).

Polycyclic aromatic hydrocarbons (PAHs), also known as poly-aromatic hydrocarbons or polynuclear aromatic hydrocarbons are chemical compounds that consist of fused aromatic rings and do not contain heteroatoms or carry substituents (Fetzer, J. C. 2000: 143).

PAHs may contain four-, five-, six- or seven-member rings, but those with five or six are most common. PAHs composed only of six-membered rings are called alternant PAHs. Certain alternant PAHs are called "benzenoid" PAHs. The name comes from benzene, an aromatic hydrocarbon with a single, six-membered ring. These can be benzene rings interconnected with each other by single carbon-carbon bonds and with no rings remaining that do not contain a complete benzene ring. PAH compounds resonance structure as the following table 1.1.

Chemical compound	Chemical compound

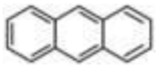
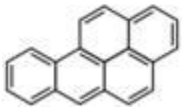
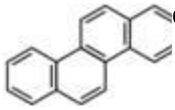
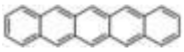
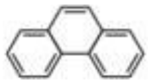
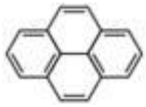
Anthracene		Benzo[a]pyrene	
Chrysene		Coronene	
Corannulene		Naphthacene	
Naphthalene		Pentacene	
Phenanthrene		Pyrene	
Triphenylene		Ovalene	

Table 1.1 PAH compounds resonance structure

Polycyclic aromatic hydrocarbons are lipophilic, meaning they mix more easily with oil than with water. The larger compounds are less water-soluble and less volatile. PAHs toxicity is very structurally dependent, with isomers (PAHs with the same formula and number of rings) varying from being non-toxic to being extremely toxic. Thus, highly carcinogenic PAHs may be small or large (Glenn, M.R. 1995: 125).

The U.S. EPA has designated 16 PAH compounds as priority pollutants from 610 PAH compounds. They are naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benz[a]anthracene, chrysene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[a]pyrene, dibenz[a,h]anthracene, benzo[g,h,i]perylene, and indeno[1,2,3-cd]pyrene. The Table 1.2 of the 16 EPA priority PAHs is often targeted for measurement in environmental samples. (Luch, A. 2005: 22-27). This research will also measure 4 PAHs concentration from 16 PAHs in the coke oven work place and the investigation will focus on the few representative compounds in the 16 PAHs such as naphthalene, phenanthrene, pyrene and benzo[a]pyrene.

Compound	**Abbr.**	**Compound**	**Abbr.**
Naphthalene	Nap	Chrysene	CHR
Acenaphthylene	AcPy	Benzo[a]anthracene	BaA
Acenaphthene	Acp	Benzo[b]fluoranthene	BbF
Fluorene	Flu	Benzo[k]fluoranthene	BkF
Phenanthrene	PA	Benzo[a]pyrene	BaP
Anthracene	Ant	Dibenzo[a,h]anthrancene	DBA
Fluoranthene	FL	Indeno[c,d]pyrene	IND
Pyrene	Pyr	Benzo[g,h,i]perylene	BghiP

Table 1.2 Sixteen EPA priority PAHs that are often targeted for measurement in environmental samples

1.2 Aim of the research

The aim of the research is to evaluate the exposure levels of workers to polycyclic aromatic hydrocarbons (PAHs) at a coke-oven workplace.

1.2.1 Sub-question 1

Are there differences in the PAHs exposure levels of coke oven workers that work in the different oven positions: (i) oven top, (ii) oven side and (iii) oven bottom?

The objective of this question is to determine whether PAHs exposure levels have difference to the executions of stay in different positions for each coke oven (coke oven A and coke oven B).

1.2.2 Sub-question 2

What is the difference between the PAHs exposure levels to coke oven N (new oven) and coke oven O (old oven)?

The objective is to compare PAHs exposure level between coke ovens N (new oven) and coke oven O (old oven) in order to determine the consistency in the PAHs exposure levels between ovens and if differences do occur, what could be the cause.

1.2.3 Sub-question 3

What is the PAHs exposure level to coke oven workers associated with the different job roles?

The objective is to compare PAHs exposure level with different job roles in close proximity and further away from the coke oven in order to improve the management of the different work positions in order to reduce the worker’s exposure to PAHs.

1.2.4 Sub-question 4

What control measures can be implemented to each coke oven to reduce PAH exposure to workers?

The objective is to develop a sustainable management control program to reduce the negative health effects associated to the PAHs exposures associated base on the characteristics of each coke oven and the different work positions.

1.3 Research Variables

CONCEPTIONAL DEFINITION OF VARIABLE	OPERATIONAL DEFINITION I.E. INDICATOR	SCALE OF MEASUREMENT	TYPE OF VARIABLE	DATA CODING
1. **Position**	The area of measurement (oven roof, oven side and oven bottom)	Ordinal	Categorical	Codes are created
2. **PAHs**	The representative PAH compounds exposure of coke-oven workplace	Ordinal	Categorical	Codes are created
3. **Exposure time**	The measurement area under of exposure	Continuous	Ratio	-
4. **Coke ovens**	The different coke ovens (new oven and old oven)	Binary	Categorical	New oven=N Old oven=O
5. **Job roles**	The different roles of coke-oven workers	Ordinal	Categorical	Codes are created

Table 1.3 Independent Variables

1.4 Description of coke making process

Coke making is an important process of steel making. The coke making process consists of a coal dry distillation process which is done under high temperature (1300^{0}C-1400^{0}C) to remove volatile components and is a vital and largely irreplaceable component of the metallurgical industry (See Figure 1.2). In the coke-making process, bituminous coal is fed (usually after the processing operations to control the size and quality of the feed) into a series of coke oven batteries, which are sealed and heated at high temperatures in the absence of oxygen, typically in cycles lasting 14 to 36 hours (Yang, L. 2002: 752-756c). Volatile compounds that are driven off the coal are collected and processed to recover combustible gases and other by-products. The solid carbon remaining in the oven is coke. It is taken to the quench tower, where it is cooled with a water spray or by circulating an inert gas (nitrogen). This process is also known as dry quenching where after it is screened and sent to a blast furnace or to storage. The coke oven gas is cooled, and by-products are recovered. Flushing liquid, formed from the cooling of coke oven gas, and liquid from primary coolers contains tar and are sent to a tar decanter. An electrostatic precipitator is used to remove further tar from coke oven gas. The tar is then sent to a place of storage. Ammonia liquor is also separated from the tar decanter and sent to wastewater treatment after the ammonia recovery. After this, the coke oven gas is further cooled in a final cooler where naphthalene is removed in the separator of the final cooler. Light oil is then removed from the coke oven gas and is fractionated to recover benzene, toluene, and xylene. During the coke quenching, handling, and screening operation, coke breeze is produced which is either reused on site, or sold off site as a by-product (Martinez, Z. 2009: 37). The coke making process is summarised in Figure 1.2.

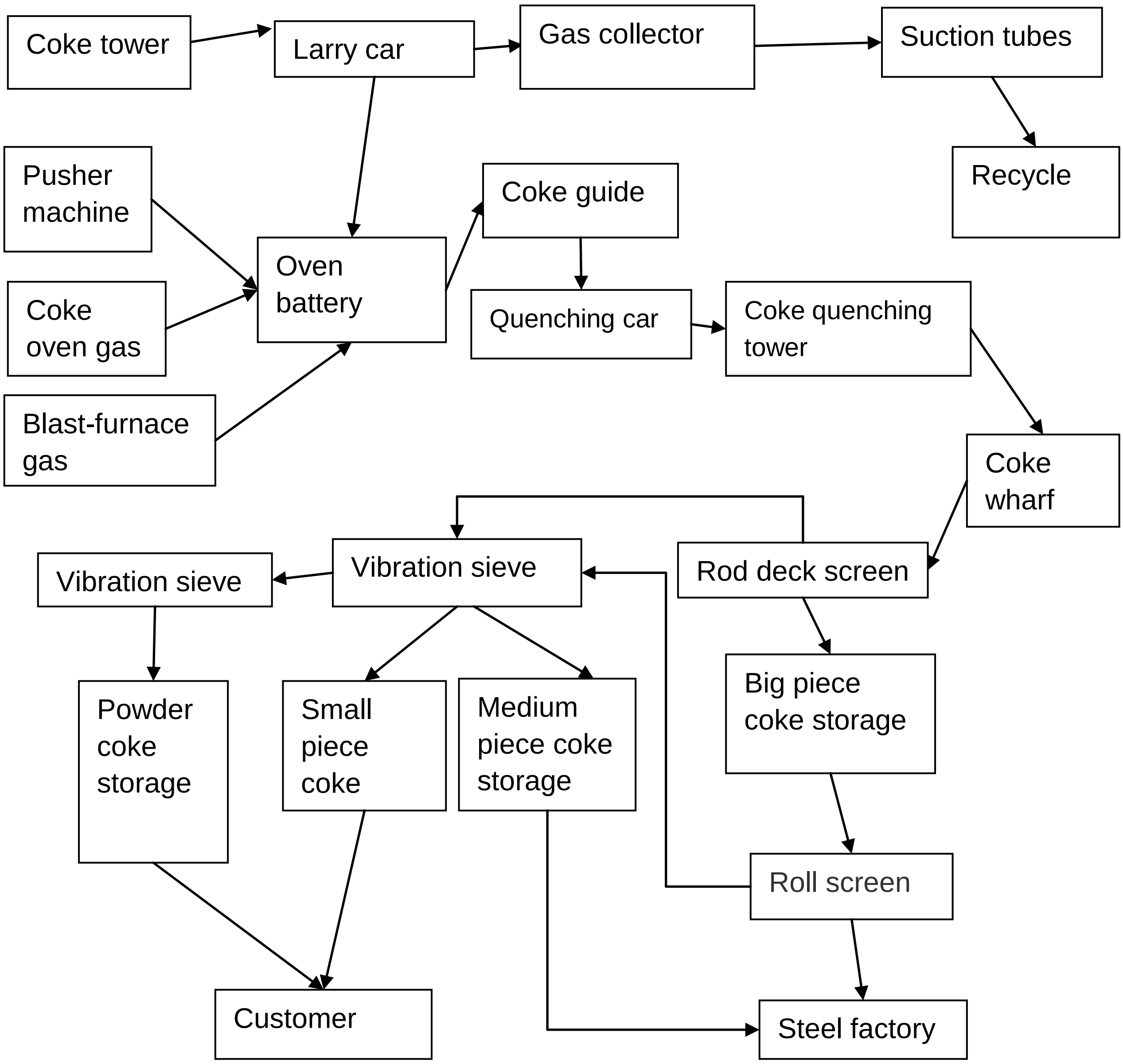


Figure 1.2 Coke making process

The coke oven battery is the main part of coke oven. The coal dry distillation process is finished in the coke oven battery. The coke oven battery consists of many identical coking chambers, a raw gas receiver and throttle devices arranged in the receiver to control the gas pressure in the chambers individually. Each throttle device includes an immersion bucket acted upon by water. Gas lines terminating in immersion pipes in the immersion buckets connect the chambers with the receiver. Throttle devices are employed that include an overflow that can be vertically adjusted by an actuating drive for controlling the liquid level in the immersion bucket. For a coking chamber to which a pressure control device is allotted, the setting signals for the actuating drive is allocated to the time pressure curve in the process of carbonising coal to coke are recorded as a position-time curve. The actuating drives of throttle devices that are allocated to coking chambers without pressure control devices, are controlled according to the position-time curve.

Figure 1.3 Coke side of a coke oven battery. The oven has just been "pushed" and railroad car is full of incandescent coke that will now be taken to the "quench station".

Figure 1.4 Coke oven top work environment

Figure 1.5 Coke oven front side work environment

Figure 1.6 Coke oven back side work environment

Figure 1.7 Coke oven bottom work environment

CHAPTER 2

LITERATURE REVIEW ON COKE OVEN INDUSTRY AND PAH HEALTH EFFECTS

This chapter starts by describing the relationships between the coke making technique, coke-oven emissions and health effects. This section also specifies that the coke making technique can influence PAHs exposure levels in close proximity of the oven and its operations. For instance, with proper control, the coke oven workers can have a lower PAHs exposure to coke oven workers. This section will also argue that workers that are exposed to high levels of PAHs are associated to negative adverse health effects.

2.1 Coke description

Coke is a solid carbon fuel and carbon source used to melt and reduce iron ore. On average, about 500 kg of coke is consumed to produce one ton of hot metal. It may be noted that, coke plays an important role in the chemical reaction during the blast furnace (BF) iron making process. Good quality coke is indispensable to the BF-BOF process route, and hence coke ovens comprise of an important part of the integrated steel mill (US. EPA. 1984; US. EPA. 1987).

Coke and coke by-products, including coke oven gas, are produced by the pyrolysis (heating in the absence of air) of suitable grades of coal. The process also includes the processing of coke oven gas to remove tar, ammonia (usually recovered as ammonium sulphate), phenol, naphthalene, light oil, and sulphur before the gas is used as fuel for heating the ovens (Bhowmik, B. 2009: 7).

Hot metal production via conventional blast furnace is closely linked with the use of coke and therefore, its availability is of extreme importance according to the specifications. Coke is the critical fuel of integrated iron and steel plants. It must possess certain properties in order that blast furnaces operate effectively. It should comprise of large well-graded lumps with few fines. According to Graham, coke plays three vital roles in blast furnace operation, namely: physical, thermal and chemical (Graham, J.D. 1989: 4-5).

Physical: Coke, especially as the only solid material downwards of the melting zone, assures the necessary permeability to the furnace gas below, above and in the cohesive zone itself. Also, the coke bed works as a kind of basis to the huge weight of the overlying burden inside the reactor, requiring a suitable mechanical strength.

Thermal: The burning of the carbon content in the coke through the oxygen of the hot blast provides most of the energy used in the process.

Chemical: Coke is the carbon bearing material which gasifies and forms the reducing gas CO, needed for the indirect reduction of the iron oxides in the upper part of the blast furnace. Moreover, coke is responsible for the direct reduction of the remaining FeO, SiO, MnO, etc., and for the carburisation of the molten iron (Jones, A. 2004).

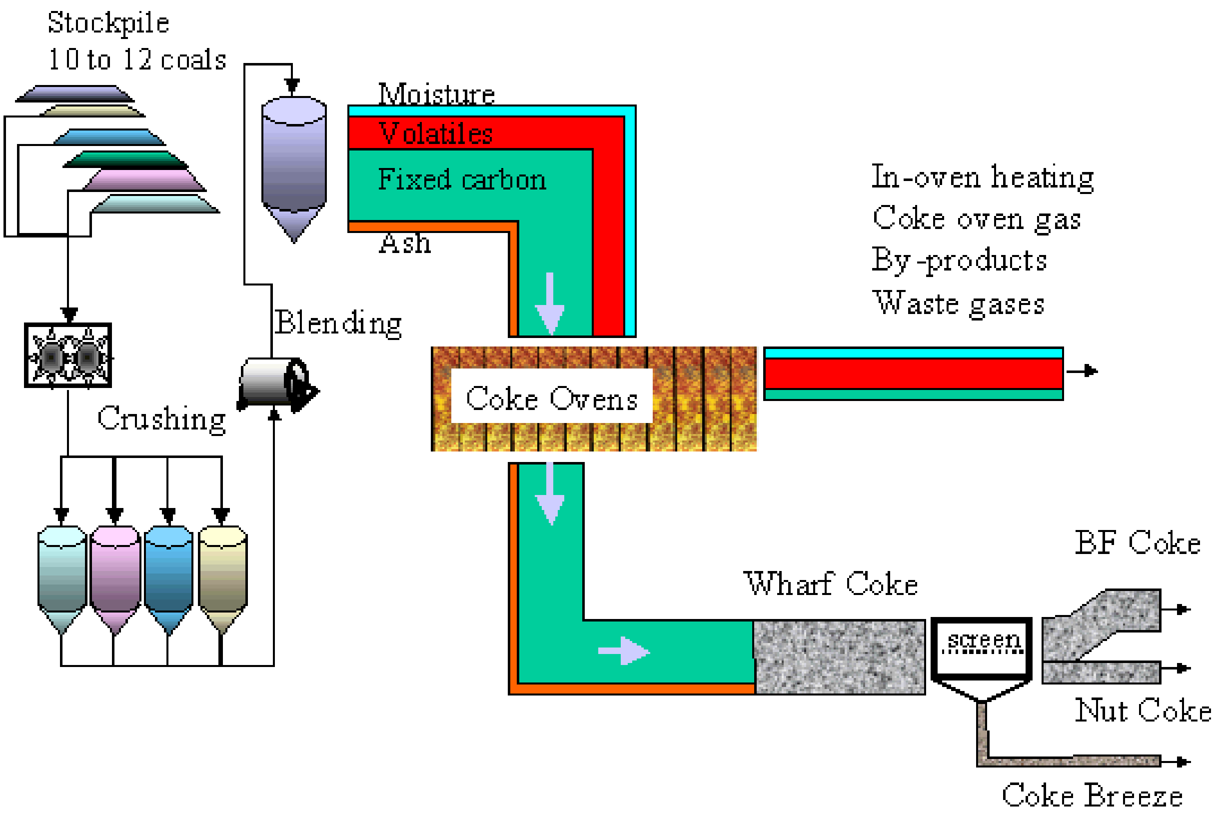


Figure 2.1 Coke making procedures

2.2 Coke oven description

The major components of a coke oven comprises of a larry car, the coke oven battery, coke pushing car, coke guide car, and quenching car.

2.2.1 Larry car

A coal larry car (Figure 2.1), also called a coal charging car, is a kind of coke oven equipment on the top of coke oven applied to convey coal from the coal tower to the carbonisation room through the charging hole.

A coal larry car is composed of steel framework, running mechanism, loading device, baffle plate, feeding pipe, vibration device, and pneumatic (hydraulic) system, power distribution system and cab (Stellman, J.M. 1998: 147).

Figure 2.2 Larry car

2.2.2 Coke oven battery

In a typical coke oven battery (Figure 2.3), a number of coke ovens are lined up in a chamber. This chamber is called the battery. Each oven in the battery has doors on top and on two sides (the other two sides abut neighbouring ovens). Above and to one end of the battery is a coal storage bin. On the top of the battery is a movable larry car which is able to take coal from the storage bin and drop it into specific coke ovens. On one side of the battery is a movable coke pushing car which is able to push coke (made from coal) out of the ovens and into a movable coke quenching car located on the other side of the ovens (Stellman, J.M. 1998: 147).

Figure 2.3 Coke oven battery

2.2.3 Coke pushing car

Coke pushing cars (Figure 2.4) are applied to push coke cakes out of the carbonisation chamber. Before or after pushing, the side oven port will be accordingly opened and closed for the plumbago to be cleaned out. Before or after coal is levelled, the small port will be accordingly opened and closed. Moving back and forth on the side trial of the oven, the coke pusher gradually finishes all works according to the order of coke pushing.

The functions of the coke-pushing car are side port opening and closing, coke pushing, coal levelling, etc. Its main structure comprises of a steel framework, travelling mechanism, side port opening device, coke-pushing device, plumb ago cleaning device, coal levelling device, pneumatic system, lubrication system, and distribution system and driving cab (Inayama. 2003: 84).

Figure 2.4 Coke pushing car

2.2.4 Coke guide car

Equipped at the operation desk of the discharging side (Figure 2.5), a coke guide car is used to take and load cokes from the side port. While pushing, the grid of the coke guide leads the red coke into the coke car and the sooth into the dust leg. During this procedure, the coke guide car carries out the automatic opening and closing of the oven doors.

A typically coke guide car comprises of a port-lifting device, a coke guide device, and a travelling and cleaning mechanism. In order to prevent the coke guide from recession while the coke guide car is travelling, a locking device for the coke guide is also adopted.

A coke guide car is usually applied in working conditions where there are narrow spaces, high temperatures, thick dusts and smokes and it is required from the coke guide car to open and close the oven port, locate the coke guide precisely and easily (Stellman, J.M. 1998: 48).

Figure 2.5 Coke guide car

2.2.5 Coke quenching car

A coke quenching car is used to convey the coke from the carbonisation chamber to the coke quenching tower and have the quenched coke unloaded to coke wharf (Figure 2.6). (Toll, H. 2000: 4-6)

Figure 2.6 Coke quenching car

2.2.6 Locomotive

Locomotive (Figure 2.7) transfers coke from the oven to the quench tower and then onto a wharf.

Figure 2.7 Locomotive

2.3 Coke oven operation

The coke oven operation can be classified into 4 steps (Figure 2.8-Figure 2.11). The larry car takes small loads of coal from the coal tower and drops them into the coke ovens called comprising of a number of ovens called a battery. This dumping procedure requires that lids on top of the ovens in the battery be automatically or manually opened and closed. After the coal load is dumped into an oven, a leveller bar flattens the pile of coal into a bed. This allows a space for the waste gas to collect while the coal is being heated. The coal is heated from below by a combustion gas system. The gas consists of largely air and waste gas taken from earlier cycles of coke production (Camp, J. M. 1985: 167-171). Virtually all of the gas is recovered and reused in the coke production process. This gas is primarily composed of hydrogen and methane with water vapour; tar, light oils, and heavy hydrocarbons (among other compounds) are also present. Steam jets force the gas trapped between the hot coal and the oven top into a collecting gooseneck. Then the gas is sprayed with a flushing liquid and cooled somewhat.

After the tars, light oils, ammonia, phenol, and hydrogen sulphide are taken from the gas, it is sent back to the coke oven - this time into the side heating units (Martinez, Z. 2009: 24-31).

When the coal has been heated sufficiently, doors on both sides of the oven are opened. A pusher car comes along and literally pushes the hot coke out of the oven into a quench car. The car takes the hot material to a quenching tower. The coke is drenched with water and cooled for transport and size screening. If the coal has been heated for a sufficient length of time, this pushing operation poses little problem. However, if the coal (not yet coke) is prematurely pushed from the oven, flames and large quantities of volatile gases shoot out from the oven. This sort of incident is called a green push, or pushing a bomb. It can only be avoided and controlled through good brickwork, careful training of coke oven workers, good work practices and maintenance of heating systems.

As stated above, most of the gas in a coke oven is recycled and reused. However, some emissions do escape during the charging, coking and pushing phases. Through, the topside lids, push side doors, and quench car side doors, and general cracks do also leak to a small extent. The amount of such fugitive emissions depends on numerous factors such as the design, age and condition of the battery, as well as the operating and maintenance practices employed on the battery.

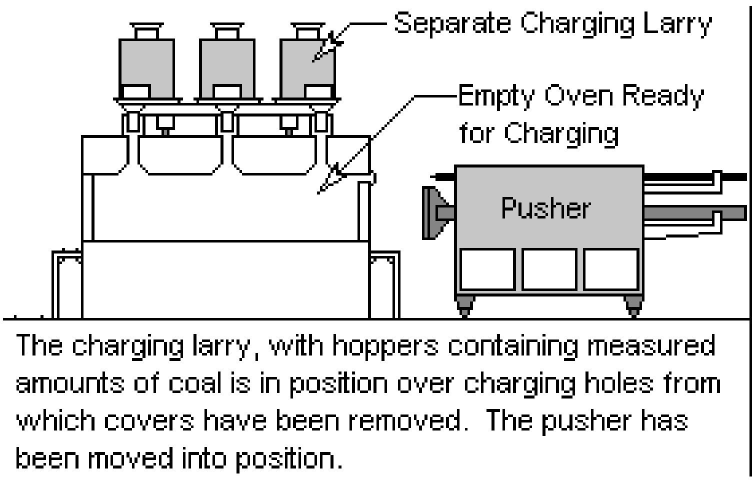


Figure 2.8 Coking step 1

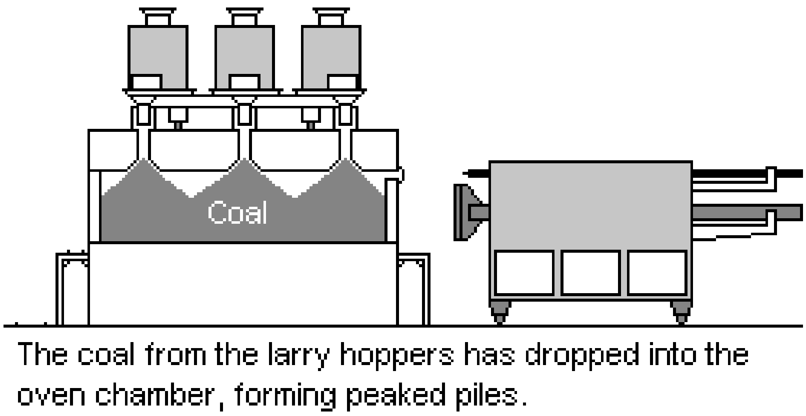


Figure 2.9 Coking step 2

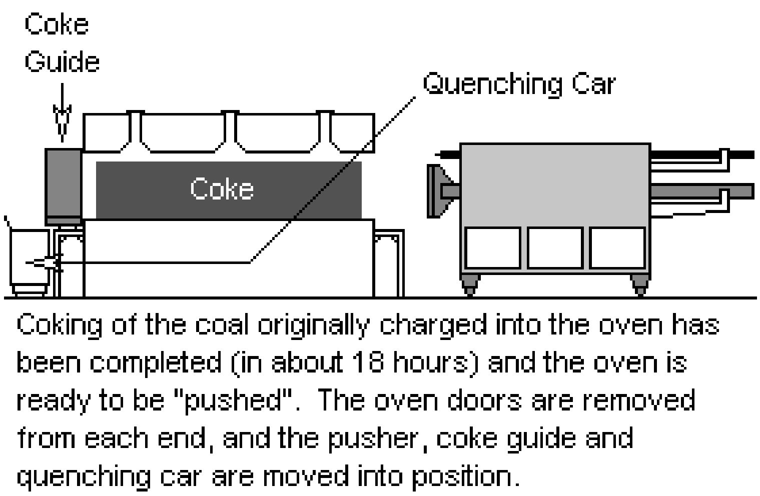


Figure 2.10 Coking step 3

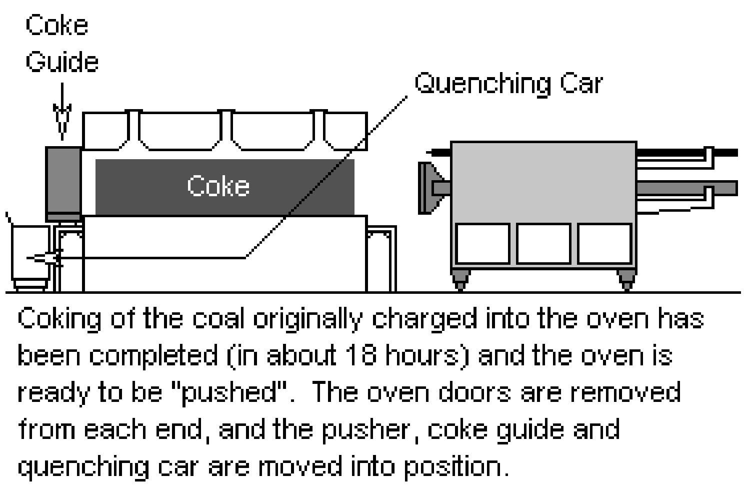


Figure 2.11 Coking step 4 (Association of Iron and Steel Engineers, 1985)

2.4 Coke oven worker job roles description

2.4.1 Job: Larry car operator

Area: Oven top

The larry car operator fills the hopper on the larry car by means of levers on the side of the car, drives the car into position above the charging holes and discharges the coal into these ports. It is also his task to attend to the standpipes. These duties involve that the operator would at times be exposed to black smoke, both inside and outside the larry car cab. It is to be mentioned that some workers spend all of their working time on the top of the ovens.

2.4.2 Job: Oven lidsman

Area: Oven top

The lidsman opens the charging port and repositions the lids after charging. The lids are sealed to reduce the escape of volatile materials. During his workday he spends more time close to the lids than for instance, the larry car driver.

2.4.3 Job: Coke pushing car driver

Area: Oven side

The coke pushing car driver works in a cab some distance from the side of the oven. He is responsible for directing the levelling bar into the oven to redistribute the coal and push the coke out into the coke guide car on the other side of the oven after the coking process has been completed.

2.4.5 Job: Coke guide car driver

Area: Oven side

He removes the coke side door using a machine and positions the coke guide so that the pushed coke is directed into the guide car.

2.4.6 Job: Coke quenching car driver

Area: Oven side

The coke quenching car driver drives the coke quenching car to take the coke to quenching tower for quenching.

2.4.7 Job: Coke car operator

Area: Away from the ovens

The coke car operator drives the locomotive that pulls the wagons from the oven to the quench tower and then onto a wharf. He spends all of his time during a normal working day in the cab of his loco.

2.5 Coke oven emissions

Coke oven emissions are a yellowish-brown gas containing upwards of 10,000 compounds, e.g., gases, vapours, PAHs and particulates. Several of these constituents are known carcinogens. Especially problematic emissions for human life are benzene, PAHs organic matter, respirable particulate matter, and coal tar pitch volatiles.

A typical coke oven produces about 80 % coke, 12 % coke oven gas, and 3% coal tar. Coke oven gas is made up of 58 % hydrogen, 26 % methane, 11 % nitrogen, 7 % carbon monoxide, and 3 % heavier hydrocarbons (Sax, N.I. 1987: 244-237).

Coke oven emissions are known to be human carcinogens (IARC. 1984; IARC. 1987). Epidemiological studies have shown an increase in incidences of lung cancer in humans that are exposed to coke oven emissions. Mortality studies have demonstrated an increase in lung and genitourinary system cancers among coke oven workers. An IARC Working Group also stated that there is limited evidence that such occupational exposures induce cancer of the kidney and that there is inadequate evidence for intestinal and pancreatic cancers associated with coke oven emissions (IARC. 1984). EPA estimated that 1.5 to 16 lung cancer deaths per year are associated with exposure to coke oven emissions.

In the US EPA report 1984 on extensive epidemiological studies of coke oven workers, it is mentioned that workers exposed to coke oven emissions are at an increased risk of cancer. A dose-response relationship was established in terms of both length of employment and intensity of exposure according to the work area at the top or side of the coke oven. The relative risk of lung, trachea and bronchus cancer mortality in 1975 was 6.94 among Allegheny County, Pennsylvania coke oven workers who had been employed five or more years from 1953 and worked full time on the topside of the coke ovens. By comparison, side oven workers employed more than 5 years had a relative risk of 1.91, while non-oven workers employed more than 5 years had a relative risk of 1.11.

Sakabe, H., Tsuchiya, K. and Tahekura, N. (1975) observed a significant ($P < 0.05$) excess of lung cancer deaths (lung cancer mortality ratio of 2.37) among retired iron and steel coke oven workers in Japan when compared to expected lung cancer mortality ratio derived from general population statistics. Mutagenicity tests on the complex mixture of solvent-extracted organics of coke oven emissions have shown to positive in bacteria. A complex mixture from the coke oven collecting main proved to be mutagenic in bacteria and mammalian cells in vitro. In addition, a number of components identified in coke oven emissions are recognised as mutagens and/or carcinogens.

Research was also done in China by Yunping Hu on the adverse health effects in Coke oven emissions (COEs) among exposed workers, which evaluated COE exposure with liver function and the effects of modification of potential non-occupational factors. Seven hundred and five (705) coke oven workers and 247 non-coke oven workers were selected for investigation in this study. Individual cumulative COE exposure was quantitatively estimated. Serum alanine aminotransferase (ALT), aspartate aminotransferase (AST), γ-glutamyl transferase, alkaline phosphatase, hepatitis B surface antigen and anti-hepatitis C antibodies were measured. The results showed that among those with high COE exposure, the adjusted ORs of abnormal ALT and AST were 5.23 (95% CI 2.66 to 10.27) and 1.95 (95% CI 1.18 to 3.52), respectively. Overweight individuals (body mass index (BMI) ≥25 kg/m^2) with high COE exposure had revealed possible risks of abnormal ALT (adjusted OR 23.93, 95% CI 8.73 to 65.62) and AST (adjusted OR 5.18, 95% CI 2.32 to 11.58). Risk of liver damage in hepatitis B virus- or hepatitis

C virus-positive individuals with COE exposure was also elevated. From this it seem that Long-term exposure to COE increases the risk of liver dysfunction, which is more prominent among those with higher BMI and hepatitis virus infection (Hu, Y. 2000).

2.6 PAHs description

Polycyclic aromatic hydrocarbons are lipophilic (i.e. they mix more easily with oil than water). The larger compounds are less water-soluble and less volatile (i.e., less prone to evaporate). Because of these properties, PAHs in the environment are found primarily in soil, sediment and oily substances, as opposed to in water or air. However, they are also a component of concern in particulate matter suspended in air.

In this research, coke oven PAHs exposure levels will be the primary focus of the investigation. The research will focus on a review of the PAHs in the coke oven industry. The U.S. EPA has designated 16 PAH compounds as priority pollutants from 610 PAH compounds (Table 2.1). It will also focus on few representative PAHs from this 16 PAHs (Mulas, G. 2006: 446, 537).

Molecular Formula	**Molecular Weight**	
Naphthalene	$C_{10}H_{8}$	128
Phenanthrene	$C_{14}H_{10}$	178
Anthracene	$C_{14}H_{10}$	178
Fluoranthene	$C_{16}H_{10}$	202
Pyrene	$C_{16}H_{10}$	202
Chrysene	$C_{18}H_{12}$	228
Benzo(a) anthracene	$C_{18}H_{12}$	228
Benzo(b) f luoranthene	$C_{20}H_{12}$	252
Benzo(k) f luoranthene	$C_{20}H_{12}$	252
Benzo(e) pyrene	$C_{20}H_{12}$	252
Benzo(a) pyrene	$C_{20}H_{12}$	252
Perylene	$C_{20}H_{12}$	252
Benzo(ghi) perylene	$C_{22}H_{12}$	276
Dibenzo(ah) anthracenes	$C_{22}H_{14}$	278
Indeno(cd) pyrene	$C_{22}H_{12}$	276

Coronene	$C_{24}H_{12}$	300

Table 2.1 Sixteen PAH compounds as priority pollutants from 610 PAH compounds

PAH have been identified as the markers for various sources, namely:

- Coal combustion : Phenenthrene, fluorathene and pyrene;
- Coke production : Anthracene, phenenthrene and benzo(a)pyrene;
- Incineration : Pyrene, phenenthrene and fluoranthene;
- Wood combustion : Benzo(a)pyrene and fluoranthene;
- Industrial – oil burning : Fluoranthene pyrene and chrysene;
- Petrol powered vehicles : Benzo(ghi)perylene, indeno (123-cd)pyrene and coronene;
- Diesel powered vehicles : Fluoranthene and pyrene with higher ratios of benzo(b)Fluoranthene and benzo(k)fluoranthene, plus thiophene compounds (Polenske, K.R. 2002: 57-72).

PAHs are found in all coke oven emissions and have been notarised to be a carcinogenic to the human by the International Agency for Research on Cancer (IARC) in 1984. So, PAHs exposure evaluations are very important to protect the health of the coke oven workers. The sources of PAHs can both natural and anthropogenic. Natural sources are i.e. typical forest fires, volcanic activities and bacterial decay of organic materials. On the other hand, anthropogenic sources may be divided into the following four categories.

1) Industry: Coke oven, aluminium production, iron and steel foundries, coal gasification and coke production are the main industrial sources of PAHs.

2) Automobile: Motor vehicle emissions (especially diesel vehicles) make a considerable contribution to PAH concentration in air due to burning and incomplete combustion of diesel or gasoline. Air craft engine as a source of PAH in the atmosphere has also been identified (Anon, 1999: 29-33).

3) Domestic: Cooking (fuel burning) and waste refuse incineration.

4) Human habitats: Smoking cigarettes, cigar and tobacco.

PAH*	Tunnel	Diesel engines	Gasoline engines	Coke oven	Wood combustion
2-ring	76	8.7	55	89	11
3-ring	16	56	18	8.9	69
4-ring	4.3	10	12	0.97	6.6
5-ring	3.1	18	13	0.22	13
6-ring	0.38	5.2	0.053	0.014	bd
7-ring	bd	0.18	0.082	bd	bd

Table 2.2 Source distribution of the percentage of PAHs to the total mass of 20 PAHs

(2-ring: naphthalene; 3-ring: acenaphthylene, acenaphthene, fluorine, phenanthrene, anthracene and retene; 4-ring: fluoranthene , pyrene, benz(a)anthracene, chrysene and triphenylene; 5-ring: cyclopenta(c, d)pyrene, benzo(b, k)Fluoranthene, benzo(a, e)pyrene, di benzo(ghi)perylene; 6-ring: indeno(1,2,3,cd)pyrene and benzo(ghi)pyrene; 7-ring: coronene. bd**:** below the detection limit of this study.) (B. Sengupta. 2003)

2.7 PAHs health effect

Evidence that mixtures of PAHs are carcinogenic to humans primarily originates from occupational health studies of workers based upon inhalation and dermal exposure as indicators and according to Chen, no data are available on humans for the oral route of exposure. In the past, chimneysweepers and tar-workers were dermally exposed to substantial amounts of PAHs, and PAHs were associated with skin cancer among many of these workers. However, it seems that Coke -oven workers, coal-gas workers and employees in aluminium production plants provide sufficient evidence of the possible role of inhaled, PAHs in the induction of lung cancer (Chen M.L., Mao, I.F., Wu, M.T., Chen, J.R., Ho, C.K., Smith, T.J., Wypij, D. 1999: 105-110).

2.7.1 Acute health effect

The properties of PAHs that induce short-term negative health effects in humans are not clear. Occupational exposures to high levels of pollutant mixtures containing PAHs have resulted in symptoms such as eye irritation, nausea, vomiting, diarrhoea and confusion. However, it is not known which of the mixture components were causative for these effects. Though, a mixture of

PAHs are known to cause skin effects in animals and humans, such as irritation and inflammation. Anthracene, benzo(a)pyrene and naphthalene are direct skin irritants, whilst anthracene and benzo(a)pyrene are reported to be skin sensitizers, i.e. cause an allergic skin response in animals and humans.

2.7.2 Chronic health effect

Health effects from chronic or long-term exposure to PAHs may include cataracts, kidney and liver damage and jaundice. Repeated contact with skin may induce redness and skin inflammation. Naphthalene, a specific PAH, can cause the breakdown of red blood cells if inhaled or ingested in high dosage.

Lamm has found that animals exposed to high dosage of some PAHs over long periods in laboratory studies have developed lung cancer from inhalation, stomach cancer from ingesting PAHs in food and skin cancer from skin contact (Lamm, S.H. 1983: 93-98).

Long-term studies of workers exposed to mixtures of PAHs and other workplace chemicals have shown an increased risk of skin, lung, bladder and gastrointestinal cancers (Sakabe et al. 1975: 57-68). These studies have also reported asthma-like symptoms, lung function abnormalities, chronic bronchitis and decreased immune function. However, it is not clear from these studies whether exposure to PAHs was the cause as other potential cancer-causing agents were also presents (Lloyd, J. W. 1971: 53-68).

2.7.3 Cancer risk

It is to be noted that the most significant endpoint of PAHs in humans is cancer and in this respect epidemiological studies of coke oven workers have reported an increase in cancer of the lung, trachea, bronchus, kidney, prostate, and other sites (EPA 1999; Bertrand, J.P., Chau, N., Patris, A. et al. 1987: 559-565). PAHs have been determined to be a carcinogenic to human by International Agency for Research on Cancer. Therefore, continued research regarding the mutagenic and carcinogenic effects from chronic exposure to PAHs and metabolites is needed. The following table indicates the carcinogenic classifications of selected PAHs by specific agencies (Dong, Redmond, Mazumdar & Costantino. 1988: 128-136; EPA. 1984).

Agency	PAH Compound(s)	Carcinogenic Classification
U.S. Department of Health and Human Services (HHS)	• benz(a)anthracene, • benzo(b)fluoranthene, • benzo(a)pyrene, • dibenz(a,h)anthracene, and • indeno(1,2,3-c,d)pyrene.	Known animal carcinogens
	• benz(a)anthracene and • benzo(a)pyrene.	Probably carcinogenic to humans
International Agency for Research on Cancer (IARC)	• benzo(a)fluoranthene, • benzo(k)fluoranthene, and • ideno(1,2,3-c,d)pyrene.	Possibly carcinogenic to humans
	• anthracene, • benzo(g,h,i)perylene, • benzo(e)pyrene, • chrysene, • fluoranthene, • fluorene, • phenanthrene, and • pyrene.	Not classifiable as to their carcinogenicity to humans
U.S. Environmental Protection Agency (EPA)	• benz(a)anthracene, • benzo(a)pyrene, • benzo(b)fluoranthene, • benzo(k)fluoranthene, • chrysene, • dibenz(a,h)anthracene, and • indeno(1,2,3-c,d)pyrene.	Probable human carcinogens
	• acenaphthylene, • anthracene, • benzo(g,h,i)perylene, • fluoranthene, • fluorene, • phenanthrene, and pyrene.	Not classifiable

Table 2.3 Carcinogenic classifications of selected PAHs by specific agencies (IARC. 1987; EPA. 1987)

2.8 PAHs exposure limits

COMPOUND (alphabetically)	OSHA	NIOSH	ACGIH
1. ACENAPHTHENE	--	--	--
2. ACENAPHTHYLENE	--	--	--
3. ANTHRACENE	0.2 mg/m^3	--	--
4. BENZ[A]ANTHRACENE	--	--	--
5. BENZO[B]FLUORANTHENE	--	--	suspect carcinogen
6. BENZO[K]FLUORANTHENE	--	--	--
7. BENZO[GHI]PERYLENE	--	--	--
8. BENZO[A]PYRENE	0.2 mg/m^3 (benzene sol.)	0.1 mg/m^3 (cyclohexane sol.)	suspect carcinogen
9. BENZO[E]PYRENE	--	--	--
10. CHRYSENE	0.2 mg/m^3 (benzene sol.)	lowest feasible, carcinogen	suspect carcinogen
11. DIBENZ[A,H]ANTHRACENE	--	--	--
12. FLUORANTHENE	--	--	--
13. FLUORENE	--	--	--
14. INDENO[1,2,3-CD]PYRENE	--	--	--
15. NAPHTHALENE	10 ppm	10 ppm; STEL 15 ppm	10 ppm; STEL 15 ppm
16. PHENANTHRENE	0.2 mg/m^3	--	--
17. PYRENE	--	--	--

Table 2.4 PAHs exposure limits by OSHA, NIOSH and ACGIH (NIOSH, 5515)

2.9 PAH measurement equipment

The measurement and analysis of PAHs usually use gas chromatography (GC). In this research, the HAPSITE Smart man-portable GC for environmental measurement and N6890 GC to analysis personal samples were used. The principles of GC are described below.

2.9.1 HAPSITE Smart man-portable GC

HAPSITE Smart is considered to be one of the most powerful, truly portable analytical tools available for field use. The totally self-contained system with pre-programmed methods and 32-bit architecture for more versatile data processing means an operator can simply power up the instrument to enable the appropriate method, establish specified temperatures, and automatically tune the instrument if necessary. HAPSITE Smart signals when ready, and begins the sample acquisition with the push of a button. Complete analysis results, including chromatograms, spectra, library search results and quantitative data, are displayed on a screen (INFICON, 2004).

The HAPSITE Smart was designed for on-scene detection, identification and quantification of toxic industrial chemicals (TICs) and chemical warfare agents (CWAs) and provides results when and where they are needed. The GC/MS is the benchmark for positive identification of organic chemicals with the highest degree of accuracy of any available analytical technique. The confirmatory results are usually available within minutes, often necessary in practice to make critical decisions affecting life, health, safety and the emission exposure of the worker.

Figure 2.12 HAPSITE Smart man portable GC

The HAPSITE is a lightweight, rugged, easy to carry instrument that contains the gas chromatograph and mass spectrometer, as well as the sampling inlet, battery, carrier gas, internal standards, vacuum pump, control electronics, and analysis software.

2.9.1.1 HAPSITE Smart specification

The HAPSITE Smart man portable GC specification was summarised in Table 2.5

Operating Conditions	5°C to 45°C. Cold weather insulating bag and insulation available
L x W x H	18" x 17" x 7" (46 cm x 43 cm x 18 cm)
Weight	Approximately 16 kg (35 lbs) with battery
Power Supply	Rechargeable NiMH battery pack or AC inverter
Battery Life	Battery lasts approximately 3 hours before recharging is needed
Internal Power Consumption	24 V(dc), 30 watts at normal operating conditions
Sample Introduction	Direct...internal sample pump
Carrier Gas	Nitrogen (can be customized for Helium)
Data System	Integral Intel® Pentium® processor & external Windows®-based laptop (not required for operation)
Library	National Institute of Standards and Technology (NIST) and AMDIS Mass Spectral libraries; NIOSH.
SmartTune	Diagnostic software routine for self-tuning, if necessary, and preparing for sample analysis.
Detection Limits	<ppb for most analytes
Mass Spectrometer	
Mass Range	1-300 AMU
Scan Rate	1000 AMU/sec @10 points per AMU
Ionization Mode	70 eV EI
Detector	Electron multiplier
Vacuum System	Non-evaporable getter pump (NEG)
Dynamic Range	7 decades
Gas Chromatograph	
Temperature Programmable GC Column	45°C to 225°C
GC Column	30 m x .32 mm i.d. Alternate phase and film thickness options available.

Table 2.5 Specification of HAPSITE Smart (INFICON, 2004)

2.9.2 Gas chromatography

Chromatography is based on the principle that different molecules are adsorbed to a different extent by different kinds of substances. This fact can be used to separate mixtures of various substances.

In gas chromatography, the stationary phase is generally a non-volatile liquid, which coats an inactive, pulverized, solid material packed within a very long (30 meters) thin (1/4 of a millionth of a meter) column. The mobile phase is generally an inert gas such as helium and is referred to as a carrier gas (Harris, D.C. 1999: 675-712). Gas chromatography is the most widely used chromatographic technique for environmental analyses. Chromatography is the science of separation that uses a diverse group of techniques to separate closely related components of complex mixtures. During gas chromatographic separation, the sample is transported via an inert gas called the mobile phase. The mobile phase carries the sample through a coiled tubular column where analyses interact with a material called the stationary phase (McLafferty, G, R., Fred, W. 1993: 367). For separation to occur, the stationary phase must have an affinity for the analyses in the sample mixture. The mobile phase, in contrast with the stationary phase, is inert and does not interact chemically with the analyses. The only function of the mobile phase is to sweep the analyse mixture through the length of the column (Pavia, D.L., Gary M. Lampman, G.M., Kritz, S., Engel, R.G. 2006: 797-817).

The components of the mixture to be separated must be volatile (vapour pressures of at least 60 Torr). A very small amount of solution (6/10 of one millionth of a litre) is injected into the injection port of the chromatograph using a syringe. The mixture is immediately vaporized and carried by the carrier gas into the column. The column, as well as the injection port and the detector are kept at a controlled temperature inside an oven so that the mixture remains in vapour form. From the time the materials are injected into the instrument until they reach the detector, the liquid in the column retains them.

The stationary phase is chosen so that the components of the sample distribute themselves between the mobile and stationary phase to varying degrees. Those components that are strongly retained by the stationary phase move slowly, relative to the flow of the mobile phase. In contrast, components that have a lower affinity for the stationary phase travel through the column at a faster rate. As consequence of the differences in mobility, sample components separate into discrete bands that can be analysed qualitatively and quantitatively (Pavia, D.L. et al. 2006: 797-817).

The time each substance is retained is called its retention time, and is usually represented in minutes. Various techniques (for example, temperature and choice of column) are chosen so that each component of the mixture has a different retention time and, therefore, reaches the detector separately and appears as a peak on a chromatogram. There are several types of detectors, but the one used in this study was a flame ionisation detector. This detector essentially counts carbon atoms, and therefore, the area under each peak represents the amount of component in the mixture. Thus, both qualitative and quantitative information can be collected (Adlard, E. R., Handley, A.J. 2001: 23-45).

CHAPTER 3

DESIGN METHODS OF MONITORING PAHs EXPOSURE LEVEL

This chapter presents an approach for data collection and the methods for data analysis. The INFICON Company offers the only portable, gas chromatograph/mass spectrometers (GC-MS) that is commonly used in the coke oven field to identify organic compound in the air. The air sampling is induced into the INFICON GC-MS to make sure what chemical compounds are involved. In this study the personal sampling equipment was used to collect the PAHs compounds in the air for coke-oven workers. FILTER + SORBENT (2-μm, 37-mm PTFE filter + washed XAD-2,100 mg/50 mg) were used for collecting Naphthalene and PAH's samples. The personal sampling equipment and techniques were executed according to the specifications that appears in the NIOSH Manual of Analytical Methods. Each sample was analysed in a lab with GC-6890 (gas chromatograph 6890) to determine the concentration PAHs for each sample. After sample analysis the HAPSITE's Windows based software is used to compare the results in order to provide a proper risk assessment for coke oven workers.

3.1 INFICON HAPSITE Smart gas chromatograph/mass spectrometers (GC-MS) air monitoring and result

The HAPSITE Smart combines (Figure 3.1, Figure 3.2) have two analytical techniques, gas chromatography and mass spectrometry, to separate, identify, and measure the organic components in a gaseous phase sample. Using a flow of inter Nitrogen carrier gas, the gas chromatograph (GC) performs a time separation (Retention Time) of the sample compounds. The separation order is primarily based upon the increasing compound boiling point. The Mass Spectrometer (MS) detects and identifies the eluting compounds by breaking the molecules apart and detecting the fragments. The resulting mass spectrum was compared to a library of mass spectra to identify the compound.

Figure 3.1 HAPSITE Smart man portable GC-MC package 1 (2004 INFICON)

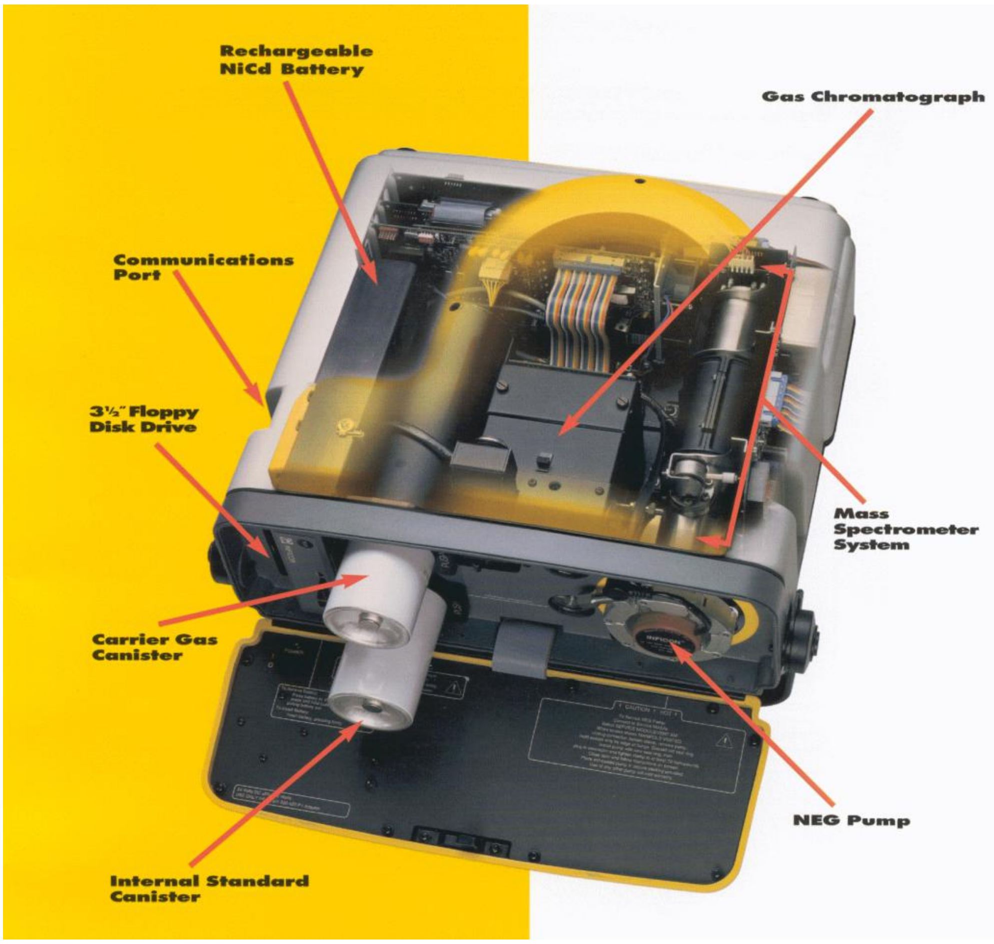


Figure 3.2 HAPSITE Smart man portable GC package 2 (2004 INFICON)

The HAPSITE mass spectrometer is self-tuning and automatically injects internal standards with each sample and when the analysis is finished, the results appears on the front panel screen. The chromatographic and spectral data are also easy to view and analysed with an external PC running HAPSITE's Windows based software. Because it is so user friendly and suitable to use in the coke oven field environment, it was selected as the most feasible data collection technique for this study.

3.1.1 Methodology of HASPITE data collection

In this research the HAPSITE monitor was placed in pre-determined strategic positions in the coke oven area to collect air samples. First the monitoring points were selected to present the different working sections surrounding the coke oven. HAPSITE collect the air samples from each point and analysed the compounds in air. The results reflect a list of the entire chemical compounds in air at that specific monitoring point.

The following steps in the HAPSITE operation were followed: (2004 INFICON)

1. Selection of an air-sampling point in the coke oven field. The coke ovens were divided into three (3) separate sections namely the (i) coke oven top, (ii) coke oven side and (iii) coke oven bottom. The HAPSITE air monitoring reflects the data from each of the mentioned sections.

2. The HAPSITE data collection technique was implemented before the GCMS-Loop monitoring function was run to calibrate the instrument. In this research, the TIC (total ion count) was over 1,000,000 with the result that it was decided to select a 30s sampling method for GCMS analysis.

3. A GCMS-Loop model was selected to monitor the air samples for each coke oven section. The GCMS-Loop has two settings that can be chosen (an AIR 15 min Loop and AIR 25 min Loop. In order to monitor organic compounds more comprehensively, the GCMS AIR 25 min Loop was set at an AIR 29 min Loop.

4. GCMS heaters stabilizing automatic warm-up instrument was activated to regular temperatures and the instrument was tuned after the heaters stabilized.

5. The intake was held to the target point and kept running for 30 seconds until air sampling finished. The flow rate was 100ml/min, which means a 50ml air sample was taken during each sampling procedure.

6. The GCMS administer AIR 29 min Loop was used to analyse sample. The GC Column 30 m x .32 mm i.d. and MS Mass Range 1-300 AMU were used for this function. The results were saved into the database.

7. GCMS was directly linked to a laptop to analyse the results with Smart IQ software. The data list received is shown below.

3.1.2 HAPSITE air sampling result

The figure 3.3 results show the organic compounds in the surrounding of the coke oven bottom work area.

14 Peaks Found for TIC						
	Ret.Time	Area	% Area			
	1:04	915669	0.02	3-Cyclohexyl-4a,5,8,8a-tetrahydrobenzo[d	Formula: C14H19NO3	CAS #: 63013263
	1:20	4.94E+08	13.14	Isopropylamine hydrochloride	Formula: C3H9N	CAS #: 15572562
	2:42	9662402	0.26	HAPSITE Internal Standard # 1 (TRIS)	Formula: C9H3F9	CAS #: 729817
	3:04	7604785	0.2	Benzene	Formula: C6H6	CAS #: 71432
	5:12	3180651	0.08	Toluene	Formula: C7H8	CAS #: 108883
	8:31	13162369	0.35	HAPSITE Internal Standard # 2 (BPFB)	Formula: C6BrF5	CAS #: 344047
	9:14	790236	0.02	p-Xylene	Formula: C8H10	CAS #: 106423
	16:08	604685	0.02	Benzene, 1-ethynyl-4-methyl-	Formula: C9H8	CAS #: 766972
	18:04	950400	0.03	Nonanal	Formula: C9H18O	CAS #: 124196
	19:56	6157113	0.16	Naphthalene	Formula: C10H8	CAS #: 91203

Figure 3.3 HAPSITE air sampling result for coke oven bottom area

The figure 3.4 shows organic compounds at coke oven side work area.

20 Peaks Found for TIC					
Ret.Time	Area	% Area	name	Formula	CAS #
0:50	526997	0.03	Carbon dioxide	Formula: CO2	CAS #: 124389
1:17	8853028	0.58	Carbon dioxide	Formula: CO2	CAS #: 124389
1:24	29793980	1.95	Ethyne, fluoro-	Formula: C2HF	CAS #: 2713099
1:47	3029020	0.2	1,3-Dioxane-4,6-dione, 2,	Formula: C6H8O4	CAS #: 2033241
1:53	4298653	0.28	Hexadecanoic acid, 1a,2,5	Formula: C36H58O6	CAS #: 52557263
2:39	5333275	0.35	HAPSITE Internal Standard	Formula: C9H3F9	CAS #: 729817
3:02	24533968	1.6	Benzene	Formula: C6H6	CAS #: 71432
5:04	2712831	0.18	Toluene	Formula: C7H8	CAS #: 108883
8:20	7270335	0.48	HAPSITE Internal Standard	Formula: C6BrF5	CAS #: 344047
9:02	992086	0.06	p-Xylene	Formula: C8H10	CAS #: 106423
12:59	619216	0.04	Benzene, (1-methylethyl)-	Formula: C9H12	CAS #: 98828
18:06	7709321	0.5	4,7-Methano-1H-indene, oc	Formula: C10H16	CAS #: 6004382
19:49	22098892	1.44	Naphthalene	Formula: C10H8	CAS #: 91203
20:05	3401667	0.22	Decanal	Formula: C10H20O	CAS #: 112312
20:17	639610	0.04	Heptadecane, 9-hexyl-	Formula: C23H48	CAS #: 55124793

Figure 3.4 HAPSITE air sampling result for coke oven side area

Figure 3.5 and figure 3.6 showed the organic compounds in the surroundings of the coke oven top work area, which is also reflected in the graphic presentation.

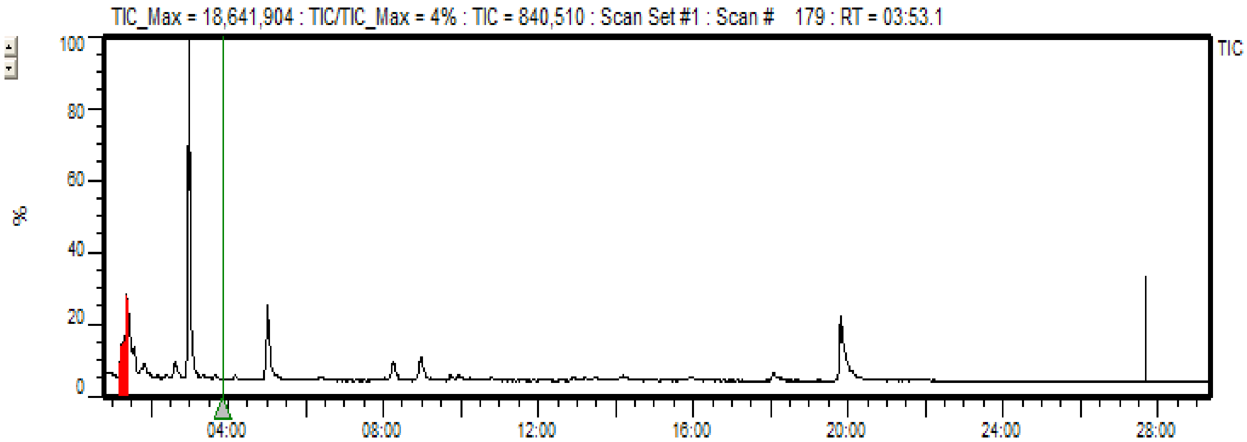


Figure 3.5 HAPSITE air sampling result for coke oven top area 1

Ret.Time	Area	% Area	Name	Formula	CAS #
1:16	8259804	0.53	Carbon dioxide	CO2	CAS #: 124389
1:22	33206258	2.11	Carbon dioxide	CO2	CAS #: 124389
1:34	6780774	0.43	Butane	C4H10	CAS #: 106978
1:44	1061242	0.07	Pentane	C5H12	CAS #: 109660
1:50	3374395	0.21	1-Propene, 2-methoxy-	C4H8O	CAS #: 116110
2:23	923208	0.06	Hexane	C6H14	CAS #: 110543
2:37	5807625	0.37	**HAPSITE Internal Standard # 1**	C9H3F9	CAS #: 729817
2:58	75425352	4.8	**Benzene**	C6H6	CAS #: 71432
3:39	1262195	0.08	Heptane	C7H16	CAS #: 142825
4:10	1444224	0.09	Cyclohexane, methyl-	C7H14	CAS #: 108872
5:00	26569182	1.69	**Toluene**	C7H8	CAS #: 108883
6:22	1120012	0.07	Octane	C8H18	CAS #: 111659
8:15	7072352	0.45	**HAPSITE Internal Standard # 2**	C6BrF5	CAS #: 344047
8:58	10256397	0.65	**p-Xylene**	C8H10	CAS #: 106423
9:44	1807059	0.11	**Styrene**	C8H8	CAS #: 100425
9:57	2519528	0.16	**o-Xylene**	C8H10	CAS #: 95476
10:14	1118355	0.07	Cyclohexane, 1,4-dimethyl-2-octade	C26H52	CAS #: 55282025
10:46	903849	0.06	Nonane	C9H20	CAS #: 111842
14:11	2784220	0.18	Benzene, 1,2,4-trimethyl-	C9H12	CAS #: 95636
15:55	1532037	0.1	**Indene**	C9H8	CAS #: 95136
18:04	3065440	0.19	4,7-Methano-1H-indene, octahydro-	C10H16	CAS #: 6004382
19:48	32670358	2.08	**Naphthalene**	C10H8	CAS #: 91203

Figure 3.6 HAPSITE air sampling results for coke oven top area 2

The results shows the organic compounds involved in the air samples taken in the pre-determined coke oven environment (coke oven bottom; coke oven side; coke oven top). However, because of the temperature limit and the instrument operation was set to regular, the HAPSITE sampling did not achieve the expected purpose. The HAPSITE sampling was performed during summer on 29th of July 2009 in BenXi China. The outdoor temperature was over 30°C and the temperature was 50 °C~60 °C around the coke oven. The HAPSITE operation condition only allows for a 5 °C~45 °C variance in temperature. The result was that the heat was a variable that had an impacted on the air sampling result.

As the focus was on PAHs and based on the HAPSITE results, traces of Indene and Naphthalene were found, which belong to PAHs compounds. No other PAHs category compounds were found from HAPSITE sampling readings. However, it is to be remembered that the existence of PAHs in the coke oven environment has already been proven. The HAPSITE result confirms the hypothesis.

3.2 Methodology and target population of personal sampling

Measurements of occupational exposure to PAHs are usually done through the personal sampling technique over a full work shift and personal sampling is generally seen as the most effective method to measure exposure levels of workers. This study followed suite and the personal sampling was implemented to measure the PAHs exposure for a full work shift among coke oven workers.

Sixty nine (69) samples were taken using the personal sampling technique. Fifty four (54) coke oven workers were randomly selected to be in the experimental group, and 15 non-workers were randomly selected to be in the control group. The measurement was performed over a period of two days. Twenty seven (27) case samples were taken during each day. The 54 coke oven workers worked at the two selected coke ovens which were the old coke oven (build in 1930s) and the new coke oven (build in 1980s). Eighteen (18) coke oven workers were from the old coke oven and 26 coke oven workers were from the new coke oven. The 54 workers were also represented from the different coke oven sections (coke oven top; coke oven side; coke oven bottom) with different job classifications. Each respondent were given a number (1-54) and the working positions are reflected in table 3.1 and 3.2.

	Oven top	**Oven side**	**Oven bottom**	**Total number of workers**
Old coke oven	5 samples (23; 26; 42; 48; 54)	9 samples (5; 16; 17; 18; 24; 35; 40; 45; 46)	4 samples (4; 22; 49; 52)	18 samples
New coke oven	14 samples (1; 6; 7; 8; 9; 20; 21; 30; 31; 33; 34; 36; 39; 44)	15 samples (2; 3; 11; 13; 14; 15; 19; 25; 28; 37; 38; 41; 43; 47; 53)	7 samples (10; 12; 27; 29; 32; 50; 51)	26 samples

Table 3.1: The number of samples in each coke oven section

	Job classification	Old coke oven	New coke oven	Number of samples
Oven top	Lidman	None	5 samples (1; 9; 31; 36; 39;)	5 samples
	Tar chaser	2 samples (23; 42)	4 samples (6; 7; 33; 44;)	6 samples
	Larry car operator	2 samples (26; 48)	5 samples (8; 20; 21; 30; 34;)	7 samples
Oven side	Pusher machine operator	2 samples (17; 45)	9 samples (2; 11; 13; 14; 25; 28; 37; 43; 47)	11 samples
	Quenching car operator	7 samples (5; 16; 18; 24; 35; 40; 46)	6 samples (3; 15; 19; 38; 41; 53)	13samples
Oven bottom	Temperature control operator	2 samples (4; 52)	6 samples (10; 12; 27; 29; 50; 51 ;)	8 samples
	Screening station operator	3 samples (22; 49; 54)	1 sample (32)	4 samples
Total		18	36	**54**

Table3.2: The number of samples for each job classification

For the control group, workers were selected that do not work in close proximity of the coke ovens. For this purposes 15 samples were selected during a full work shift.

In this research, the NIOSH Manual of Analytical Methods (NMAM) was followed to operate personal sampling measurement and the NIOSH method 5515 for POLYNUCLEAR AROMATIC HYDROCARBONS by GC was selected for this measurement.

3.2.1 Equipment for this personal sampling measurement:

Sampling measurements were done according NIOSH 5515 method quoted below:

1.	Filter. PTFE-laminated membrane filter, 2-μm pore size, 37-mm diameter in cassette filter holder. (Figure 3.7)	USA, SKC Company
2.	Sorbent tube, connected to filter with minimum length PVC tubing. Plastic caps are required after sampling. Washed XAD-2 resin (front = 100 mg; back = 50 mg) (Supelco ORBO 43). (Figure 3.8)	USA, SUPLECO Company
3.	Personal sampling pump AirChek 2000 (Flow range:1000 to 3250 ml/min) (Figure 3.9)	USA, SKC Company
4.	Calibrator DryCal DC-Lite with a calibration certificate number	USA, Bios Company
5.	GC column DB-5 MS (30m×0.32mm×0.25μm)	USA, Agilent Company
6.	Scintillation Vial,, 22-mL, glass	USA, National Scientific Company
7.	Scintillation Vial,, 8-mL, glass	USA, National Scientific Company
8.	Ultrasonic bath Bransonic 2210	USA, Branson Company
9.	Agilent 6890N Network Gas Chromatograph (Figure 2-4)	USA, Agilent Company

Figure 3.7 Filter. PTFE-laminated membrane filter, 2-μm pore size, 37-mm diameter in cassette filter holder

Figure 3.8 Sorbent tubes, connected to filter with minimum length PVC tubing

Figure 3.9 Personal sampling pump AirChek 2000

3.2.2 Reagent:

1. PAH-mixture 610/525/550, 10.0mg/L, Chem Service
2. Acetonitrile HPLC, Dikma
3. Gas, He (≥99.999%, Beijing medical Company)

The personal sampling pump was set to 8h, 2L/min which automatically calibrated each personal sampling pump with the representative samplers in line. The pumps for personal sampling were calibrated before and after sampling and the results are documented. The pumps were calibrated with a BIOS International Calibrator. A deviation of greater than 5% in the flow rate between before and after sampling was not recorded. The filter cassette was sealed and only opened at the sampling site. The filter cassette and sorbent tube were connected to a constant flow-sampling pump. PAHs were collected using FILTER + SORBENT (2-μm, 37-mm PTFE + washed XAD-2, 100 mg/50 mg) (NIOSH 5515). Sorbent tubes adsorb vapour PAHs. Filters adsorb particulate PAHs. The sampling train was clipped within a worker's breathing zone and attached to a calibrated personal sampling pump at the worker's waist. Workers carried personal sampling equipment for a full shift. The pumps were checked every 2 hours to ensure that personal sampling pumps worked properly and to determine whether the workers follow functioned according to the prescribed instructions (Stephen, M.R. 2008: 33-38).

After removing the sampling trains from the workers, the filters were placed and sealed in a scintillation vial and the sorbent tubes were capped. All the samples were kept at -20^{o}C centigrade in a freezer to avoid volatilisation. The samples were kept in a cooler box for 2 hours transportation. The atmospheric pressure and temperature at each sampling point were recorded and samples were kept in an insulated container with bagged refrigerant for the transport thereof. Field blanks of filters and sorbent tubes were taken and analyzed for quality control purposes.

3.2.3 Sample preparation:

Sampling measurements were done according NIOSH 5515 method quoted below and refrigerated samples were handled as follows upon receipt at the laboratory.

Extract filters:

a. Five (5.0) ml of the acetonitrile chosen were added to each 22ml scintillation vial containing a filter. The media and reagent blanks were started.
b. The holders were capped and stood for 30 min in an ultrasonic bath to make analytic solution.

Desorb PAH from sorbent:

a. Each sorbent tube was scored with a file in front of the primary (larger) sorbent section after which the tube was broken at the score line.
b. Glass wool plug and XAD-2 resin were transferred to a culture tube.
c. Five (5.0) ml acetonitrile were added to each culture tube and the culture tubes were capped.

d. Samples were allowed to stand for 30 min, whilst it was occasionally swirled to make an analytic solution (NIOSH 5515).

e. All sample extracts were filtered through a 0.45-μm membrane filter.

3.2.4 Sample analysis:

One (1) ml analytic solution were transferred into a into GC sampler bottle and the GC was set according to manufacturer's recommendations and to the conditions (Agilent Technologies, Inc. 2002).

GC settings:

1. GC column DB-5MS 30m×0.32mm×0.25μm fused silica capillary;
2. Temperature injector 300 ºC;
3. Sample size 1μl;
4. Temperature detector 305 ºC;
5. Temperature program 50 ºC-100 ºC, 15 ºC/min; 100 ºC-240 ºC, 20/min, hold on 2min;240 ºC-300 ºC, 8 ºC/min, hold on 3.5min;
6. Temperature ion source 230 ºC;
7. Temperature quadrupole rods 150 ºC;
8. Solvent retain 4min;
9. SIM：Single Ion Monitor.
10. GASES-CARRIER: He 1 mL/min
11. MAKEUP: He 20 mL/min

Analysis started on each sample with the Agilent 6890N Network Gas Chromatograph. Each personal sample included a filter sample and sorbent tube sample. The filter sample and sorbent tube samples are both analysed by Agilent GC-6890.

3.2.5 Quality control and calculation:

As prescribed, the recovery (R) from filters and desorption efficiency (DE) from sorbent tubes were determine. For quality control, the XAD-2 tubes showed the mass of PAH in section B is less than 10% mass of PAH in section A for all the samples. This means all samples were effective samples in this analysis and the field blank samples of filters and sorbent tubes were taken for quality control.

The mass, µg (corrected for R or DE) of each analysis found on the filter (g), sorbent (m), blank filter (g_b) and blank sorbent (m_b) were read after which the concentration, C (mg/m ^{3}) were calculated, in the air as the sum of the particulate concentration and the vapour concentration using the actual air volume sampled, V (L). (NIOSH 5515)

$$C = \frac{g+m-g_b-m_b}{V} \quad mg/m^3$$

Figure 3.10, Agilent 6890N Network Gas Chromatograph (Agilent Technologies, Inc. 2002)

All the data were imported to an approved statistical data analyses computer package known as SPSS 16.0 for analyses. Each variable was given a unique abbreviation name to identify the meaning and purpose for the data set. The entire Numerical variable was imported into the SPSS 16.0 with number mode. The codes were appropriately designed for all categorical variables, and input to SPSS 16.0 with code mode. The reliability of data input was double checked by the researcher and checked for outliers. The analyses were performed with the SPSS 16.0. Statistical programme.

CHAPTER 4

INVESTIGATION AND ANALYZE FOR PAH EXPOSURE LEVEL

In this chapter, the effects factors associate with PAH exposure levels are evaluated. The coke oven position, coke oven worker job roles and employment period were selected as independent variables for this study. It is hypothesized that these factors could affect coke oven workers' exposure levels to PAHs. The SPSS 16.0 statistical program was used to evaluate the average PAH exposure level in order to assess the health risks for the workers and describe the exposure differences associated with the various workstations in the typical coke oven environment. For quality control, the XAD-2 tubes showed the mass of PAH in section B is less than 10% mass of PAH in section A for all the samples. This means that all samples were effective samples in this analysis. (See Appendix A for more information of data analysis.)

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4.1 The comparison of PAHs exposure level to coke oven position

The analysis includes 15 administrative workers (control group) and 54 coke oven workers from each of the two ovens (new and old coke ovens), which included 13 coke oven bottom workers, 24 coke oven side workers and 17 coke oven top workers. The total sample size was 69 workers.

The exposure level means of different coke oven positions of each PAH compound are summarized in Table 4.1. A mean difference was found in each of coke oven positions. The One-Way Analysis of Variances (One-Way ANOVA) with Tamhane is summarized in Table 4.2. The One–way ANOVA test was done with a 0.05 significance level, which in turn represents a 95% confidence level. The P-value <0.05 was found between the coke oven workers and the control group (administrative workers), which showed that there was a statistical significant difference between the data sampled from the experimental group (coke oven workers from the two coke ovens together) and the control group (administrative workers). Thus, the null hypothesis was rejected.

	Oven position		Sample size	Mean (mg/m³)	Std. Deviation	95% Confidence Interval	
						Lower Bound	Upper Bound
Nap	**Control samples**		15	1.9802585	0.9124858	1.4749407	2.4855763
	Coke oven bottom		13	49.278551	26.855612	33.049867	65.507235
	Coke oven side		24	34.214916	23.022644	24.493306	43.936526
	Coke oven top		17	37.884977	33.480139	29.842169	45.927784
	Total		69				
	Model	Fixed Effects			25.23858	31.816937	43.953017
		Random Effects				-4.8936273	80.663581
Phe	**Control samples**		15	0.2577906	0.0614489	0.2237613	0.2918198
	Coke oven bottom		13	6.3674834	4.2765764	3.7831741	8.9517927
	Coke oven side		24	7.041057	6.2474903	4.4029732	9.6791408
	Coke oven top		17	20.351743	12.809039	13.765943	26.937544
	Total		69	8.7189732	10.329977	6.2374418	11.200504
	Model	Fixed Effects			7.5878263	6.8946537	10.543293
		Random Effects				-4.8735686	22.311515
Pyr	**Control samples**		15	0.2175623	0.0425108	0.1940206	0.241104
	Coke oven bottom		13	1.7732033	1.3749421	0.9423341	2.6040724
	Coke oven side		24	2.3956003	2.0238582	1.541	3.2502007
	Coke oven top		17	8.0928121	5.6210905	5.202714	10.98291
	Total		69	3.2085114	4.2093244	2.1973213	4.2197016
	Model	Fixed Effects			3.0945746	2.4644917	3.9525312
		Random Effects				-2.3251893	8.7422122
Ben[a]P	**Control samples**		15	0.2497441	0.1067587	0.1906231	0.3088651
	Coke oven bottom		13	1.345761	1.2861985	0.568519	2.123003
	Coke oven side		24	2.0928697	1.875627	1.3008619	2.8848775
	Coke oven top		17	6.2106079	4.7297004	3.7788204	8.6423955
	Total		69	2.5659458	3.4081746	1.7472129	3.3846788
	Model	Fixed Effects			2.656909	1.9271528	3.2047389
		Random Effects				-1.6037439	6.7356356

Table 4.1 Description of means for full sample size associated with coke oven positions

		(I) Coke oven positions	(J) Coke oven positions	Mean Difference (I-J)	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Nap	Tamhane	Control samples	Coke oven bottom	-47.2982924	**0.000**	-70.6982918	-23.8982931
			Coke oven side	-32.2346576	**0.000**	-45.766205	-18.7031102
			Coke oven top	-64.0538809	**0.000**	-90.116093	-37.9916688
Phe	Tamhane	Control samples	Coke oven bottom	-6.10969286	**0.000**	-9.83561445	-2.38377127

			Coke oven side	-6.78326645	**0.000**	-10.4524981	-3.11403481
			Coke oven top	-20.0939528	**0.000**	-29.4081772	-10.7797283
Pyr	Tamhane	Control samples	Coke oven bottom	-1.55564096	**0.001**	-2.75363897	-0.35764296
			Coke oven side	-2.17803805	**0.000**	-3.36688226	-0.98919384
			Coke oven top	-7.87524977	**0.000**	-11.962719	-3.78778051
Ben[a]P	Tamhane	Control samples	Coke oven bottom	-1.09601693	**0.046**	-2.21740887	0.025375011
			Coke oven side	-1.84312558	**0.000**	-2.94645502	-0.73979615
			Coke oven top	-5.96086384	**0.000**	-9.40054104	-2.52118665

The mean difference is significant at the 0.05 level.

Table 4.2 Multiple comparison for full sample size

4.1.1 Discussion

The Figure 4.1-Figure 4.4 was created to show the exposure level difference that is based on the results of the full sample size analysis. The full sample size analysis showed the exposure level of coke oven workers was as expected, significantly higher than that of the non-workers. Also, the coke oven top exposure levels were significantly higher than the other two coke oven positions. Coke oven top PAHs exposure levels were higher than other two, probably because of the construction of the oven. The small exposure level difference was detected between the coke oven side and coke oven bottom worker position, whilst the concentration of Nap was much higher than other 3 PAH compounds in each coke oven position (Nap>Phe>Pyr> Ben[a]P). The consistency is reflected in the fact that the result of the two factories did not show any statistical significant differences, as the exposure measurements showed the same responses for the Xiaobo Yang and Unwin coke ovens.

Phe, Pyr and Ben[a]P showed an increase in the exposure levels increase trend amongst the control group < oven bottom workers < oven side workers < oven top workers. However, Nap didn’t show the same increase tendency. But, Nap, Phe, Pyr and Ben[a]P all had a statistical significant ($P \leq 0.05$) exposure related to the different working positions around the coke oven.

The difference in the exposure level between new and old coke ovens and control group related to the oven positions will be discussed in par.4.2.

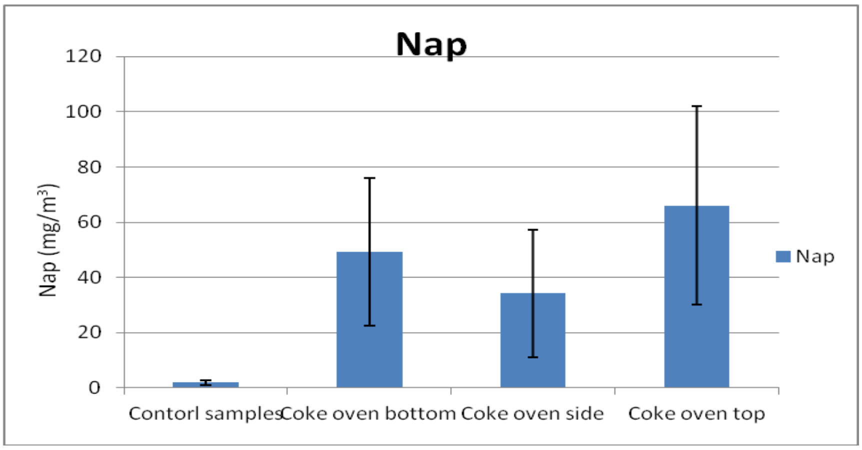

Figure 4.1 Nap exposure level associated with coke oven positions

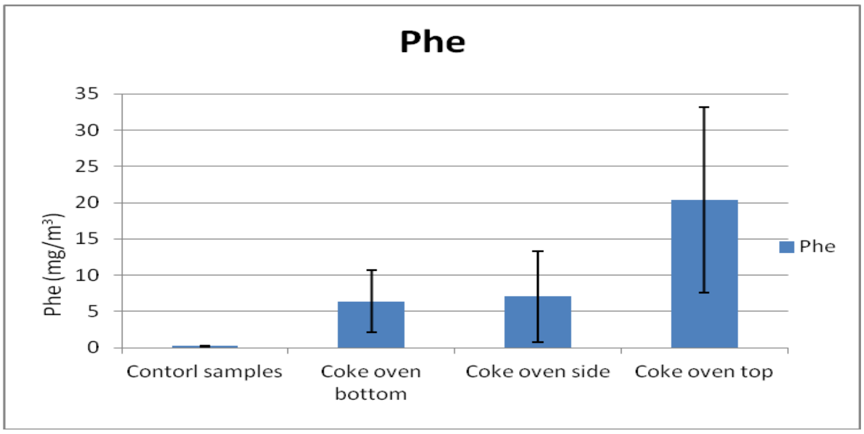

Figure 4.2 Phe exposure level associated with coke oven positions.

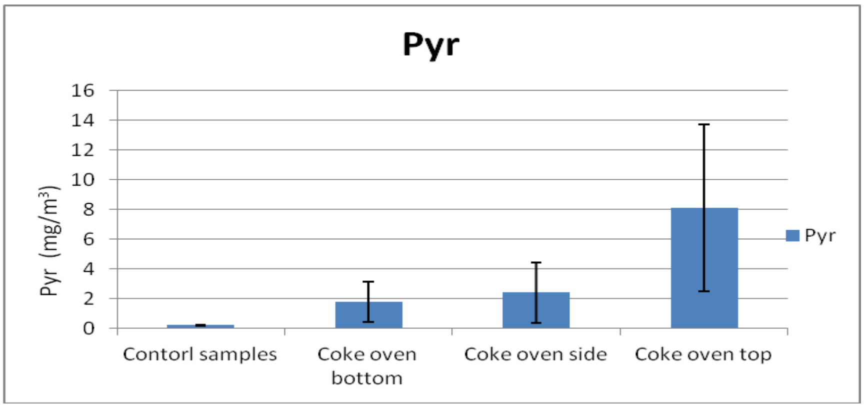

Figure 4.3 Pyr exposure level associated with coke oven positions

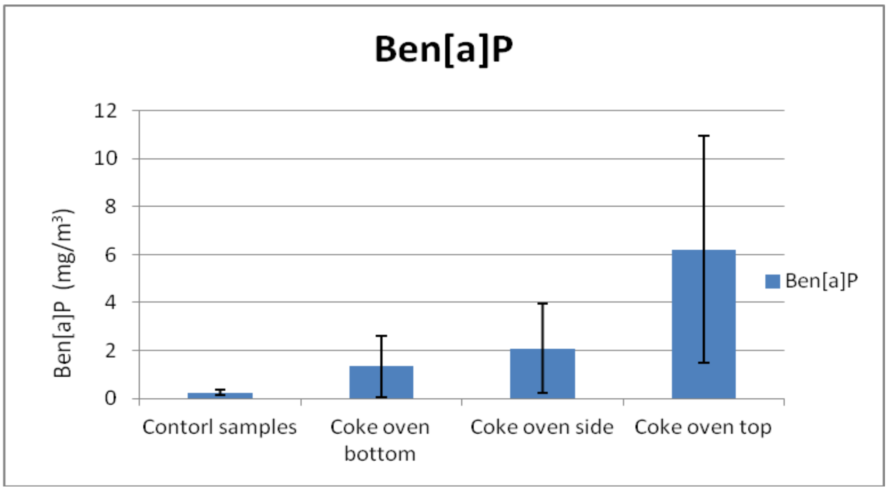

Figure 4.4 Ben[a]P exposure level associated with coke oven positions.

4.1.2 Summary

Different coke oven worker positions and administrative workers (control group) present a significant mean difference of PAH exposure levels. The data also shows that there is a significant influence between the coke oven working positions and the workers' exposure to PAH levels. In this analysis, the coke oven top workers were exposed to the highest PAH exposure level. This fact suggests that the associated health risk may be higher at this location compared to the other workstations around the coke oven.

4.2 Description of old coke oven and new coke oven workers' PAHs exposure level compare with control group at different coke oven working position

This analysis include 15 control samples, 18 samples from old coke oven (five [5] oven top samples, nine (9) oven side samples, four (4) oven bottom samples) and 26 samples from the new coke oven (13 oven top samples, 15 oven side samples and eight (8) oven bottom samples).

4.2.1 Description of PAHs exposure levels for new coke oven workers associated with different working positions

The exposure level means at different coke oven positions for the new oven is summarized in Table 4.3. A means difference was found in each of the coke oven positions between the control group on the one side and the old and new coke ovens on the other side. Because the equal variances cannot bet assumed in the results of this test, the One-Way Analysis of Variances (One-Way ANOVA) with Tamhane was performed to validate the result efficiency were performed. The One –way ANOVA test was set at a minimum of 0.05 significance level, which represents a 95% confidence.

	Oven position		Sample size	Mean (mg/m^3)	Std. Deviation	95% Confidence Interval	
						Lower Bound	Upper Bound
Nap	**control**		15	1.9802585	0.9124858	1.4749407	2.4855763
	oven bottom		8	35.067299	13.146977	24.076151	46.058447
	oven side		15	19.639853	8.0773237	15.16678	24.112925
	oven top		13	55.39757	16.208876	45.602644	65.192496
	Total		51	25.980558	22.996181	19.512778	32.448338
	Model	Fixed Effects			10.606796	22.992623	28.968493
		Random Effects				-12.676765	64.637881
Phe	**control**		15	0.2577906	0.0614489	0.2237613	0.2918198
	oven bottom		8	7.0763301	4.8323845	3.0363556	11.116305
	oven side		15	3.573742	2.5239617	2.1760186	4.9714654
	oven top		13	19.112469	8.3731547	14.052622	24.172316
	Total		51	7.1087398	8.784835	4.6379651	9.5795144
	Model	Fixed Effects			4.8246231	5.7496434	8.4678362
		Random Effects				-6.8623734	21.079853
Pyr	**control**		15	0.2175623	0.0425108	0.1940206	0.241104
	oven bottom		8	2.1321037	1.6258326	0.7728737	3.4913338
	oven side		15	1.3796553	1.2436657	0.6909362	2.0683744
	oven top		13	7.5500116	3.4652517	5.4559809	9.6440422
	Total		51	2.7287303	3.4962755	1.7453869	3.7120736
	Model	Fixed Effects			1.9801038	2.170935	3.2865255
		Random Effects				-2.761012	8.2184726
Ben[a]P	**control**		15	0.2497441	0.1067587	0.1906231	0.3088651
	oven bottom		8	1.7046877	1.5337382	0.4224505	2.9869249
	oven side		15	1.0041714	0.502552	0.7258673	1.2824754
	oven top		13	5.96195	3.2964728	3.9699114	7.9539886
	Total		51	2.1559134	2.8806536	1.3457165	2.9661103
	Model	Fixed Effects			1.7898214	1.6517207	2.6601061
		Random Effects				-2.1626846	6.4745114

Table 4.3 Description of new oven PAHs exposure level mean

The statistical significant P-values were summarized in table 4.4. In this analysis, the control group (administrative workers) and new coke oven workers (coke oven top, coke oven side and coke oven bottom workers) presented a P-value < 0.05 in the PAH means, which indicates to a rejection of the null hypothesis and a statistical significant difference in exposure levels. Thus, the analysis shows that there was a statistical significant exposure level difference between the control group and other coke oven position workers for the PAHs exposure levels test. This means the null hypothesis of no difference in PAH exposure levels in the two measurements was rejected.

Dependent Variable	(I) new oven	(J) new oven	Mean Difference (I-J)	Sig. P	95% Confidence Interval	
					Lower Bound	Upper Bound
Nap	**control**	oven bottom	33.0870401*	**.001**	49.903450	16.270630
		oven side	17.6595940*	**.000**	24.052546	11.266642
		oven top	53.4173116*	**.000**	67.543559	39.291065
Phe	**control**	oven bottom	6.8185396*	**.031**	13.002879	.634200
		oven side	3.3159514*	**.001**	5.309059	1.322844
		oven top	18.8546786*	**.000**	26.149584	11.559774
Pyr	**control**	oven bottom	1.9145415	**.023**	3.995111	.166028
		oven side	1.1620930*	**.017**	2.144286	.179900
		oven top	7.3324493*	**.000**	10.351495	4.313403
Ben[a]P	**control**	oven bottom	1.4549436	**.014**	3.416755	.506868
		oven side	.7544273*	**.000**	1.154807	.354048
		oven top	5.7122059*	**.000**	8.584477	2.839935
		oven side	4.9577787*	**.001**	2.078233	7.837325

Table 4.4 Multiple comparison for new coke oven workers with different working positions

4.2.1.1 Summary

The mean differences present a difference between control group and new coke oven workers' exposure to PAH levels. The coke oven top workers present the highest mean difference compared to the other work positions at the oven and the oven side workers presented the lowest means difference with the control group's PAH exposure levels, and the oven side workers< oven bottom workers< oven top workers.

4.2.2 Description of PAHs exposure levels for old coke oven workers associated with different working positions

The exposure level means at different coke oven positions for the old oven is summarised in Table 4.5. A means difference was found between the control group and each of the coke oven working positions in old coke oven. The equal variances not assumed were used for this test and the One-Way Analysis of Variances (One-Way ANOVA) with Tamhane was performed to validate the result efficiency. The One –way ANOVA test was set at a 0.05 significance level, which represents a 95% confidence.

	Oven position		Sample size	Mean (mg/m^3)	Std. Deviation	95% Confidence Interval	
						Lower Bound	Upper Bound
Nap old	**control**		15	1.9802585	0.9124858	1.4749407	2.4855763
	oven bottom		4	58.041366	19.14322	34.271919	81.810812
	oven side		9	66.270682	24.817891	47.193963	85.347402
	oven top		5	100.60299	60.945995	3.6243107	197.58167
	Total		33	39.962388	43.931879	24.384821	55.539955
	Model	Fixed Effects			24.598972	31.204446	48.72033
		Random Effects				39.226019	119.1508
Phe old	**control**		15	0.2577906	0.0614489	0.2237613	0.2918198
	oven bottom		4	6.6022035	2.8905988	3.013051	10.191356
	oven side		9	12.059429	7.3233253	6.4302232	17.688635
	oven top		5	24.379384	23.797578	13.487873	62.246642
	Total		33	7.3615236	11.562857	3.2615126	11.461535
	Model	Fixed Effects			8.6333316	4.287809	10.435238
		Random Effects				9.8027795	24.525827
Pyr old	**control**		15	0.2175623	0.0425108	0.1940206	0.241104
	oven bottom		4	1.494989	0.7384204	0.5781189	2.411859
	oven side		9	3.9243829	2.1927041	2.2389213	5.6098445
	oven top		5	9.8569137	7.726485	1.2113179	16.925145
	Total		33	2.5904691	4.6888229	0.9278848	4.2530534
	Model	Fixed Effects			3.6475898	1.2918222	3.889116
		Random Effects				4.0390213	9.2199595
Ben[a]P old	**control**		15	0.2497441	0.1067587	0.1906231	0.3088651
	oven bottom		4	1.3390107	1.1612573	0.1028807	2.7809021
	oven side		9	3.5920711	2.2519602	1.8610612	5.323081
	oven top		5	7.0187462	6.6429955	1.7341885	12.771681
	Total		33	2.1468133	3.7132196	0.8301629	3.4634638

Model	Fixed Effects	3.0525758	1.0600085	3.2336182
	Random Effects		2.6893981	6.9830248

Table 4.5 Description of old oven PAHs exposure level mean

The statistical significant P-values were summarized in table 4.6 In this analysis, the control group (administrative workers) and old coke oven workers (coke oven top, coke oven side and coke oven bottom workers) present the P-value < 0.05 about PAHs means, which indicates a statistical significant exposure level difference. So the analysis showed that there was a statistical significant exposure level difference between the control group and other coke oven position workers for PAHs exposure levels test, which means the null hypothesis of no difference between the two measurements was rejected.

Dependent Variable	(I) old oven	(J) old oven	Mean Difference (I-J)	Sig. P	95% Confidence Interval	
					Lower Bound	Upper Bound
Nap old	**control**	oven bottom	56.0611073*	.017	97.311299	14.810915
		oven side	64.2904240*	.000	92.947726	35.633122
		oven top	98.6227313	.045	187.075179	69.829716
Phe old	**control**	oven bottom	6.3444129*	.047	12.576635	.112191
		oven side	11.8016388*	.008	20.258593	3.344684
		oven top	24.1215939	.043	97.713328	49.470141
Pyr old	**control**	oven bottom	1.2774267	.033	2.868079	.313226
		oven side	3.7068206*	.006	6.238900	1.174742
		oven top	9.6393514	.023	22.809855	3.531152
Ben[a]P old	**control**	oven bottom	1.0892666	.042	3.586831	.408298
		oven side	3.3423270*	.013	5.942527	.742127
		oven top	26.7690021	.046	33.495001	19.956997

*. The mean difference is significant at the 0.05 level.

Table 4.6 Multiple comparison for old coke oven workers with different working positions

4.2.2.1 Summary

The means differences present a PAH exposure levels difference between the control group and old coke oven workers. The coke oven top workers present the highest means difference with control group. Oven bottom workers present the lowest means difference with control group about PAH exposure levels, with the oven bottom workers< oven side workers< oven top workers.

4.2.3 Discussion

The mean difference between the control group workers and other coke oven position workers for both new and old coke ovens were summarized in Figure 4.5-4.8. The new and old coke oven workers present a different trend of PAHs exposure levels associated with working positions, which is oven side workers< oven bottom workers< oven top workers for the new coke oven and oven side workers< oven bottom workers< oven top workers for the old coke oven. In this research, the personal sampling technique to collect air samples was used. Personal sampling shows workers exposure levels during a full 8-hour shift. In the new coke oven, coke oven top workers and coke oven bottom workers worked mostly under environmental conditions (open area). Oven side workers worked mostly in the pushing cars and quenching cars. The pushing car and quenching car in the new oven had a sealed control room with ventilation system to protect oven side workers and to reduce PAH exposure levels. The advanced equipment could be the reason why new coke oven side workers presents the lowest PAHs exposure level means difference compared to the old coke oven side workers. The difference in the exposure levels between new and old coke oven workers related to the oven positions will be discussed in par.4.3.

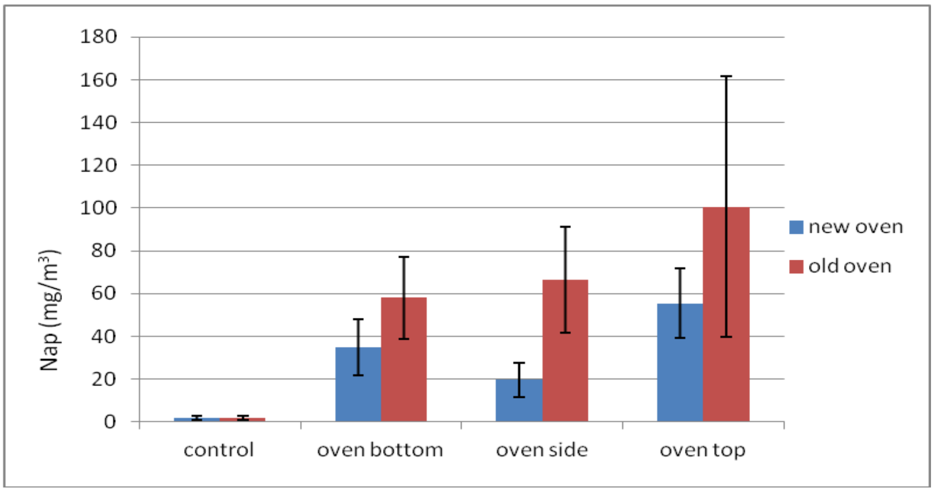

Figure 4.5 The Nap exposure level mean difference between control group and different coke oven position are associated with new and old coke ovens.

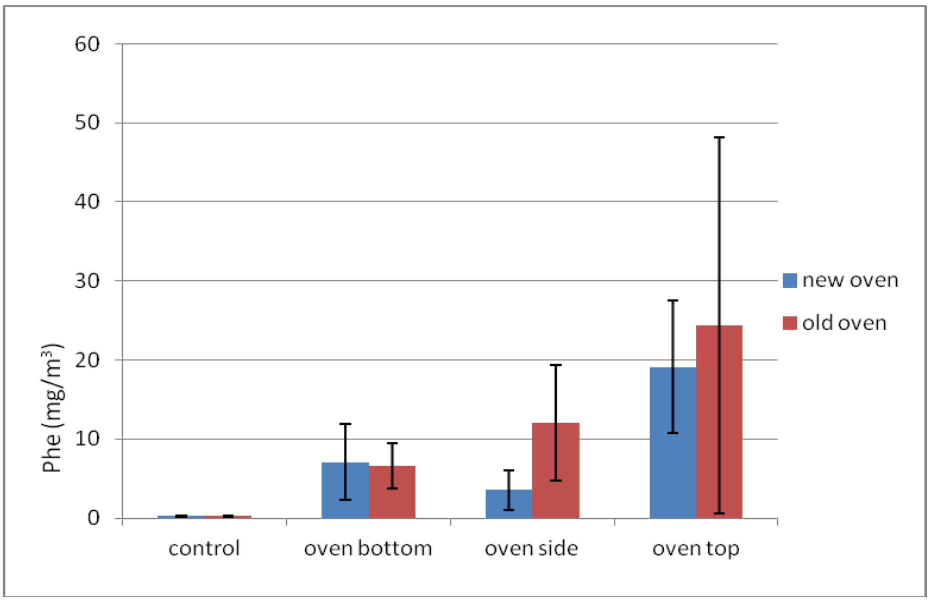

Figure 4.6 The Phe exposure level mean difference between control group and different coke oven position are associated with new and old coke ovens.

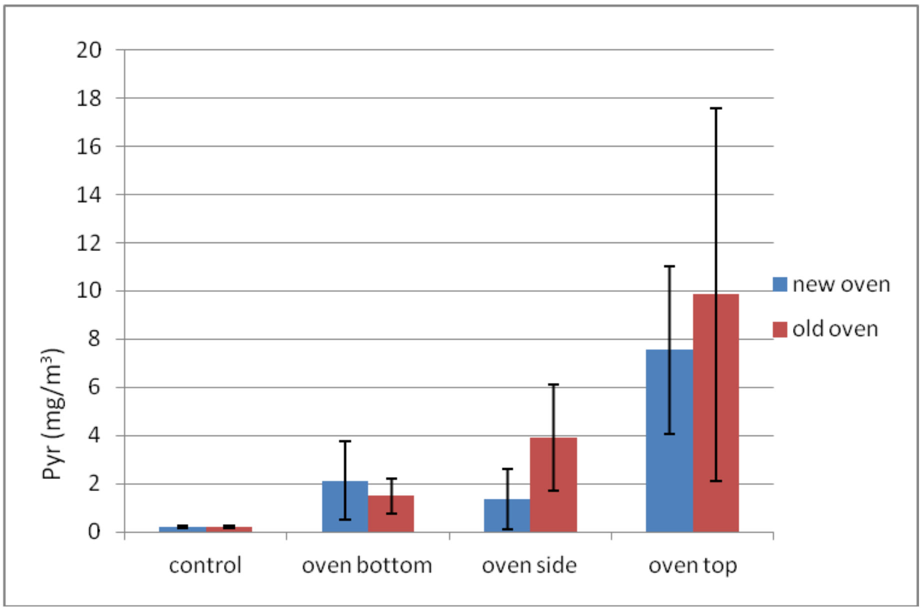

Figure 4.7 The Pyr exposure level mean difference between control group and different coke oven position are associated with new and old coke ovens.

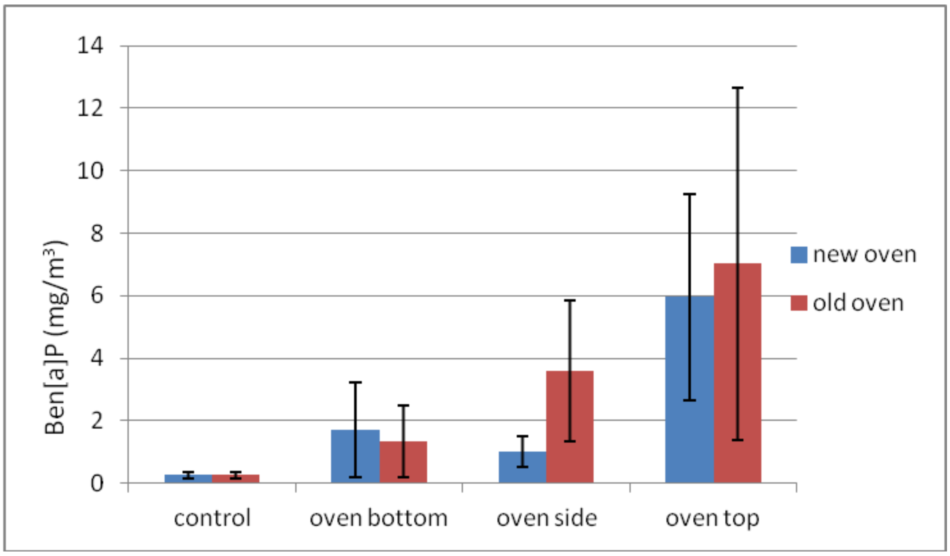

Figure 4.8 The Ben[a]P exposure level mean difference between control group and different coke oven position are associated with new and old coke ovens.

4.3 Description of the PAH exposure levels difference between new and old coke ovens associated with working positions

The analysis is to describe the PAH exposure levels difference for coke oven workers with the different working positions (coke oven top, coke oven side and coke oven bottom). The comparisons were created to evaluate the PAH exposure level differences in the same coke oven working positions between new and old coke ovens. In this analysis, the independent sample T-test to analyse the data were used. The P-value was set at a 0.05 significance level that represents a 95% confidence.

4.3.1 Description of the PAH exposure levels difference for coke oven top workers

The PAH exposure level concentration means for coke oven top workers for both old and new coke ovens, which is summarized in Table 4.7 and the mean difference and statistical significant P-value is summarized in Table 4.8.

Group Statistics					
	Coke oven top	N	Mean (mg/m³)	Std. Deviation	Std. Error Mean
Nap	old coke oven	5	103.0205	53.0568882	23.7277617
	new coke oven	13	55.39757	16.2088762	4.4955334
Phe	old coke oven	5	19.82537	22.9878010	10.2804572
	new coke oven	13	19.11247	8.3731547	2.3222953
Pyr	old coke oven	5	8.052722	10.1276186	4.5292087
	new coke oven	13	7.550012	3.4652517	.9610879
Ben[a]P	old coke oven	5	5.707504	8.0388317	3.5950748
	new coke oven	13	5.961950	3.2964728	.9142771

Table 4.7 The PAH exposure level means for coke oven top workers for both old and new coke ovens

		Levene's Test for Equality of Variances		t-test for Equality of Means				
		F	Sig.	t	df	Sig. (2-tailed)	95% Confidence Interval of the Difference	
							Lower	Upper
Nap	Equal variances assumed	7.075	.017	3.015	16	.008	14.1409784	81.1049505
	Equal variances not assumed			1.972	4.290	.115	-17.6749090	112.9208379
Phe	Equal variances assumed	4.496	.050	.100	16	.922	-14.4478341	15.8736266
	Equal variances not assumed			.068	4.415	.949	-27.4963437	28.9221362
Pyr	Equal variances assumed	5.205	.037	.162	16	.873	-6.0638211	7.0692412
	Equal variances not assumed			.109	4.365	.918	-11.9389634	12.9443836
Ben[a]P	Equal variances assumed	3.762	.070	-.098	16	.923	-5.7542932	5.2454001
	Equal variances not assumed			-.069	4.528	.948	-10.0970469	9.5881539

Table 4.8 Independent sample T-test mean difference and statistical significant P-value

Levene’s test for Nap P=0.017<0.05, Pyr P=0.037<0.05, indicate that the equal variances not assumed was calculated for Nap and Pyr. The Phe P=0.05=0.05, Ben[a]P=0.07>0.05 indicate that the equal variances assumed was calculated for Phe and Ben[a]P. The T-test for equality of means shows that the Nap P=0.115>0.05, Phe P=0.922>0.05, Pyr P=0.918 and Ben[a]P P=0.948>0.05. Therefore, the analysis indicated that there was no statistical significant difference for Nap, Phe, Pyr and Ben[a]P between old coke oven top workers and new coke oven top workers, which in turn means the null hypothesis of no difference between old coke oven top workers and new coke oven top workers was accepted.

4.3.1.1 Discussion

The analysis showed that the Nap exposure level means revealed a difference between new oven top workers and old oven top workers. The results of further analysis of the data revealed that for Nap, Phe, Pyr and Ben[a]P did not present a significant exposure level difference between the old and new coke oven top workers. The duties of the coke oven top workers are mostly to work as a lidman, larry car driver and tar chaser. It is to be mentioned that the larry cars for both new and old coke ovens were of a similar design. Therefore, it seems that larry car drivers can be sufficiently protected from PAHs by working inside with a ventilation system and air conditioning. For other coke oven top workers, that normally worked in the open the workers exposure levels were detected as closer to the condition in the vicinity of the coke oven. Therefore, new and old coke oven top workers did not present a statistical significant difference for Phe, Pyr and Ben[a]P.

4.3.2 Description of the PAHs exposure level difference for coke oven side workers

The PAHs exposure level means for coke oven side workers for both old and new coke ovens, is summarized in Table 4.9 and the mean difference and statistical significant P-value is summarized in Table 4.10.

Group Statistics					
	Coke oven side	N	Mean (mg/m³)	Std. Deviation	Std. Error Mean
Nap	Old oven	8	60.46818	18.9105032	6.6858725
	New oven	15	19.63985	8.0773237	2.0855560
Phe	Old oven	8	13.36570	6.6137588	2.3383168
	New oven	15	3.573742	2.5239617	.6516841
Pyr	Old oven	8	4.310437	1.9904384	.7037262
	New oven	15	1.379655	1.2436657	.3211131
Ben[a]P	Old oven	8	3.983263	2.0546928	.7264436
	New oven	15	1.004171	.5025520	.1297584

Table 4.9 The PAH exposure level means for coke oven side workers for both old and new coke ovens

		Levene's Test for Equality of Variances		t-test for Equality of Means					
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference Lower	Upper
Nap	Equal variances assumed	4.687	.042	7.311	21	.000	40.8283260	29.2152611	52.4413910
	Equal variances not assumed			5.830	8.389	.000	40.8283260	24.8073630	56.8492890
Phe	Equal variances assumed	13.923	.001	5.155	21	.000	9.7919549	5.8414501	13.7424597
	Equal variances not assumed			4.034	8.105	.004	9.7919549	4.2069115	15.3769983
Pyr	Equal variances assumed	4.751	.041	4.365	21	.000	2.9307813	1.5345683	4.3269943
	Equal variances not assumed			3.789	10.00	.004	2.9307813	1.2072941	4.6542685
Ben[a]P	Equal variances assumed	11.352	.003	5.421	21	.000	2.9790920	1.8362594	4.1219247
	Equal variances not assumed			4.037	7.450	.004	2.9790920	1.2552792	4.7029049

Table 4.10 Independent sample T-test mean difference and statistical significant P-value

Levene's test: Nap P=0.042<0.05, Phe P=0.001<0.05, Pyr P=0.041<0.05 and Ben[a]P P=0.003<0.05, therefore the equal variances not assumed was found for Nap, Phe, Pyr and Ben[a]P. The T-test for equality of means: Nap P=0.000<0.05, Phe P=0.004<0.05, Pyr P=0.004<0.05 and Ben[a]P P=0.004<0.05. Therefore, the analysis showed a statistical significant difference between old coke oven side workers and new coke oven side workers associated with Nap, Phe, Pyr and Ben[a]P, which in turn means the null hypothesis of no difference between the two measurements was rejected.

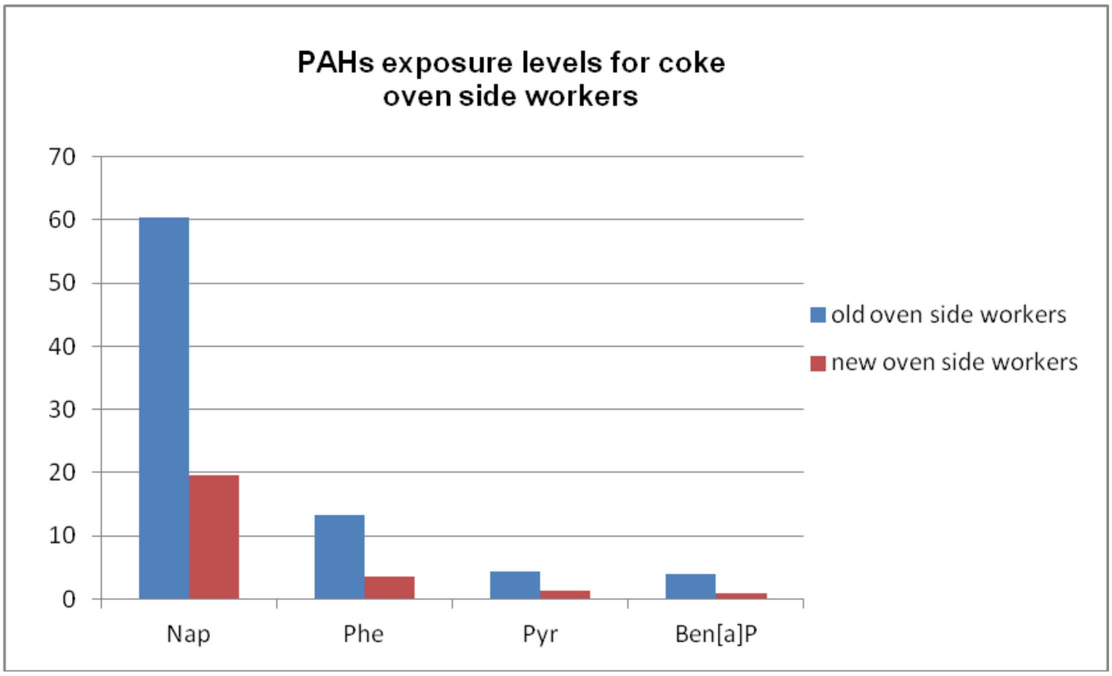

Figure 4.9 PAHs exposure levels for coke oven side workers

4.3.2.1 Discussions

The Figure 4.9 present the PAH exposure level means for both new and old oven side workers. The analysis showed that the PAHs exposure level means had an observable difference between new oven side workers and old oven side workers. The PAHs (Nap, Phe, Pyr and Ben[a]P) exposure level of old oven side workers was greater than new oven side workers. The coke oven side workers were mostly engaged as quenching car drivers and pushing car drivers. The out-of -date equipment were still used to old coke oven quenching car and pushing car. This could be a possible contributing factor to the phenomenon that the old coke oven side workers presented a higher PAHs exposure level than the new coke oven side workers. The difference in the exposure levels between new and old coke oven seems toe be clearly related to the job roles and will be discussed in par.4.4.

4.3.3 Description of the PAHs exposure level difference for coke oven bottom workers

The PAHs exposure level means for coke oven bottom workers for both old and new coke ovens, which was summarized in Table 4.11. The mean difference and statistical significant P-values are summarized in Table 4.12.

Group Statistics					
	Group	**N**	**Mean (mg/m³)**	**Std. Deviation**	**Std. Error Mean**
Nap	**Old oven**	5	5.804137E1	19.1432196	8.5611081
	New oven	7	3.573708E1	14.0521578	5.3112164
Phe	**Old oven**	5	6.602203E0	2.8905988	1.2927151
	New oven	7	7.777706E0	4.7594748	1.7989124
Pyr	**Old oven**	5	1.494989E0	.7384204	.3302317
	New oven	7	2.360611E0	1.6113792	.6090441
Ben[a]P	**Old oven**	5	1.339011E0	1.1612573	.5193301
	New oven	7	1.852406E0	1.5939733	.6024653

Table 4.11 The PAH exposure level means for coke oven bottom workers for both old and new coke ovens

		Levene's Test for Equality of Variances		t-test for Equality of Means				
		F	**Sig.**	**t**	**df**	**Sig. (2-tailed)**	**95% Confidence Interval of the Difference**	
							Lower	**Upper**
Nap	**Equal variances assumed**	1.140	.311	2.340	10	.051	1.0633574	43.5452076
	Equal variances not assumed			2.214	6.982	.063	-1.5312387	46.1398037
Phe	**Equal variances assumed**	4.895	.051	-.488	10	.636	-6.5442858	4.1932806

	Equal variances not assumed			-.531	9.855	.607	-6.1211921	3.7701869
Pyr	**Equal variances assumed**	1.372	.269	-1.109	10	.293	-2.6043199	.8730765
	Equal variances not assumed			-1.249	8.893	.243	-2.4357356	.7044922
Ben[a]P	**Equal variances assumed**	.429	.527	-.610	10	.555	-2.3876941	1.3609029
	Equal variances not assumed			-.645	9.971	.533	-2.2863594	1.2595682

Table 4.12 Independent sample T-test mean difference and statistical significant P-value

Results of Levene's test showed the following: Nap P=0.311>0.05, Phe P=0.051>0.05, Pyr P=0.269>0.05 and Ben[a]P P=0.527>0.05. Therefore, the equal variances assumed was found for Nap, Phe, Pyr and Ben[a]P. The T-test for equality of means: Nap P=0.051>0.05, Phe P=0.636>0.05, Pyr P=0.293>0.05 and Ben[a]P P=0.555>0.05. The analysis showed that there were no statistical significant difference between old coke oven bottom workers and new coke oven bottom workers associated with Nap, Phe, Pyr and Ben[a]P, which means the null hypothesis of no difference between the two measurements was accepted.

4.3.3.1 Discussion

The analysis did not present statistical significant exposure level differences between old and new coke oven bottom workers associated with Nap, Phe, Pyr and Ben[a]P. The coke oven bottom workers were mostly working as temperature controller and screen station workers. For both new and old coke ovens, the coke oven bottom workers worked mostly in the control room. The rest rooms were situated close to the control room. The new coke oven control room and rest room had a more consummate ventilation and insulation system compared to the old coke oven. However, the new coke oven bottom workers and old coke oven bottom workers still presented a no statistical significant difference of PAHs exposure levels. A possible reason for this is the difference in the design of the structure. In the new coke oven setting the control room and rest room was on the ground floor that is under the coke oven batteries, whilst in the old coke oven setting the control room and rest room was in the basement, which means there is a further distance between exposure resource and control room in the old coke oven. This influence may be the contributing factor to why the new coke oven bottom workers did not present a lower PAHs exposure level than old coke oven bottom workers.

4.4 Description of job roles associated with job duties for both new and old coke ovens

This analysis include 15 non-workers (control), 18 old coke oven workers (1 Lidman, 2 Tar chasers, 2 Larry car divers, 3 Pushing car divers, 6 Quenching car drivers, 2 Temperature controllers and 2 Screen station workers) and 26 new coke oven workers (5 Lidman, 4 Tar chasers, 5 Larry car divers, 9 Pushing car divers, 6 Quenching car drivers, 6 Temperature controllers and 1 Screen station workers). The exposure levels for workers with different job roles were evaluated in this analysis. Coke oven top job roles included the lidman, tar chaser and larry car driver. Coke oven side job roles included pushing car driver and Quenching car driver. Coke oven bottom job roles included temperature controller and screen station workers.

4.4.1 Evaluation for coke oven top job roles

In both new and old coke ovens, the exposure levels for lidman, tar chaser workers and Larry car drivers were greater than non-workers (control group). The tar chaser workers exposure level was as expected higher than lidman and larry car drivers for both old and new coke ovens. Lidman and larry car drivers presented a similar exposure levels.

The lidman opens the charging port and repositions the lids after charging the oven. The lids are sealed to reduce the escape of volatile materials. The lidman spend the rest of his time in the larry car during intermission. Larry car divers drive the car into position above the charging holes and discharge the coal into these ports. He also attends to the conditions of the standpipes. These duties necessarily involve the occasional exposure to high PAH levels both inside and outside the larry car cab. The tar chaser workers spend a lot of time outside and are naturally exposed to high levels of PAHs. However, they tend to stay in restroom during intermissions. The restroom was situated on both side of coke oven top, which is close to the high PAH exposure area. Therefore, the tar chaser workers may have had a longer period of exposure to high PAH exposure levels than lidman and larry car drivers during a 8 hours working shift. In this analysis, the significant PAH exposure levels differences between the new and old oven top workers associated with different job roles, were not found.

4.4.2 Evaluation for coke oven side job roles

The pushing car drivers worked on the front side of coke oven. Quenching car drivers worked on the backside of the coke oven. Pushing car drivers drive the car to open the chamber door and to push the coke out into the quenching car on the other side of the oven after coking. The coke quenching car drivers drive the quenching car to take coke to the quenching tower for quenching. The quenching car drivers and pushing car drivers are both briefly exposed to high PAH exposure level during the times that the chamber door opened and the coke pushing process.

In this analysis it was found that the exposure levels of quenching car drivers and pushing car drivers in the old coke oven was significant higher than the new coke oven pushing car drivers and quenching car drivers. In the new coke oven, the quenching car and pushing car had a proper air-conditioned control room that efficiently controlled the coke oven emissions. In the old coke oven, the quenching car and pushing car operators did not have a proper designed control room. Drivers had a greater exposure to coke oven emissions. The difference in the exposure levels between the new and old coke oven workers related to the pushing job and quenching job will be discussed in par. 4.5.

4.4.3 Evaluation for coke oven bottom job roles

Temperature controllers and screen station workers spent most of their working time at the coke oven bottom. The duty of screen station workers is to monitor the coking procedures on a computer. They worked in the control room for a full shift (8 hours). The coke oven bottom had a lower PAH exposure level compared to the other coke oven positions. The control room was in the coke oven bottom area with good ventilation, with the result that temperature controllers had a low chance to be exposed to high levels of PAH exposure while working in that area. Temperature controllers worked in the bottom position of the coke oven. The primary duty of a temperature controller is to regulate temperature for each coke oven chamber. They are also required to check the temperature for coke oven raiser pipes in coke oven top area and adjusted in coke oven bottom area. The PAH exposure level for the coke oven top was higher than that for the coke oven bottom. The temperature controller worked occasionally in the coke oven top area, so they were exposed to high PAH levels for relative short periods of time only. In this analysis, no significant difference was found between new and old coke oven bottom workers associated with these job roles. For both new and old coke ovens, the rest rooms were close to the control room. The new coke oven control room and rest room had a better ventilation and insulation system than the old coke oven. Still, the new coke oven bottom workers presented no statistical significant PAH exposure level differences compared to the old coke ovens. The difference is not statistical significant.   Thus, you do not have to explain the differences. Rather try to explain why there is no difference?.

Figures 4.10 – 4.13 showed PAH exposure levels for both new and old coke oven workers associated with different job roles.

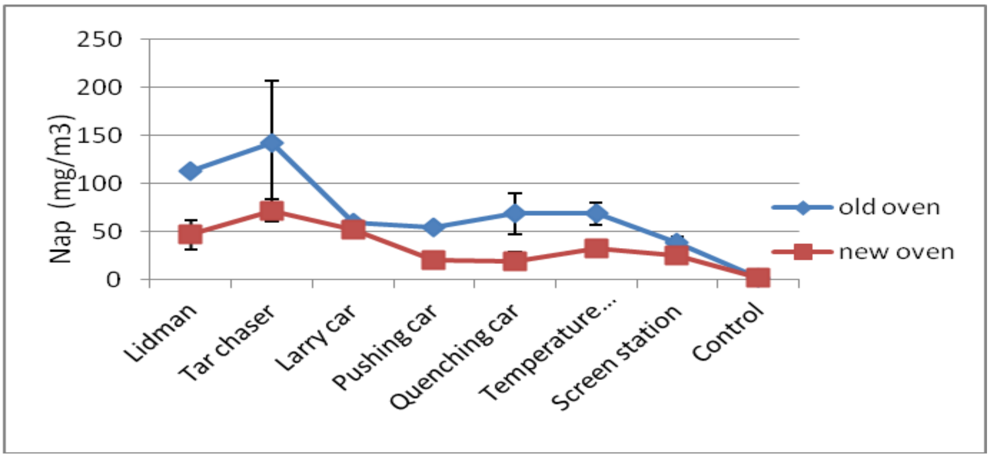

Figure 4.10 Nap exposure levels for both new and old coke oven workers associated with different job roles

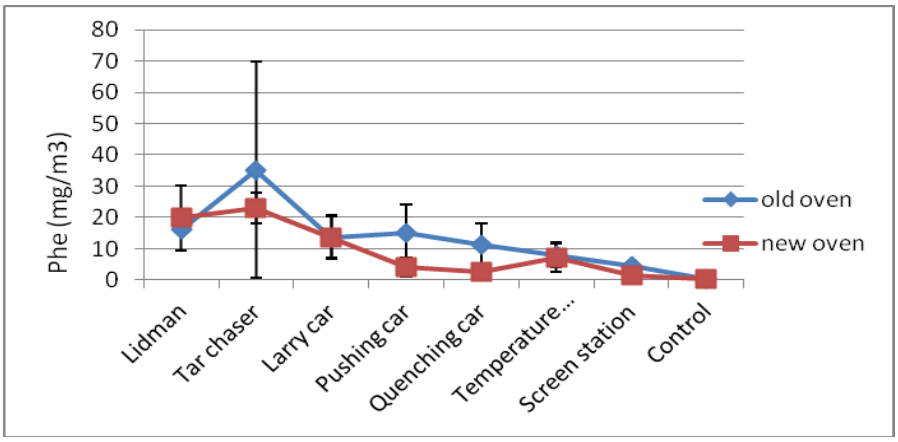

Figure 4.11 Phe exposure levels for both new and old coke oven workers associated with different job roles

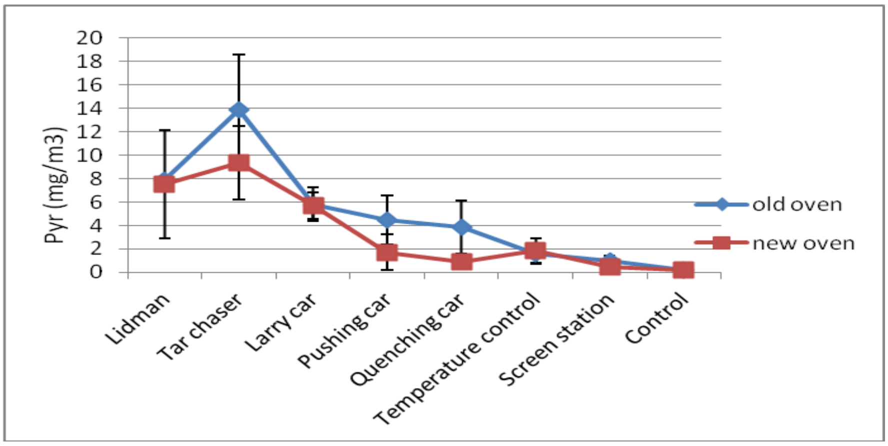

Figure 4.12 Pyr exposure levels for both new and old coke oven workers associated with different job roles

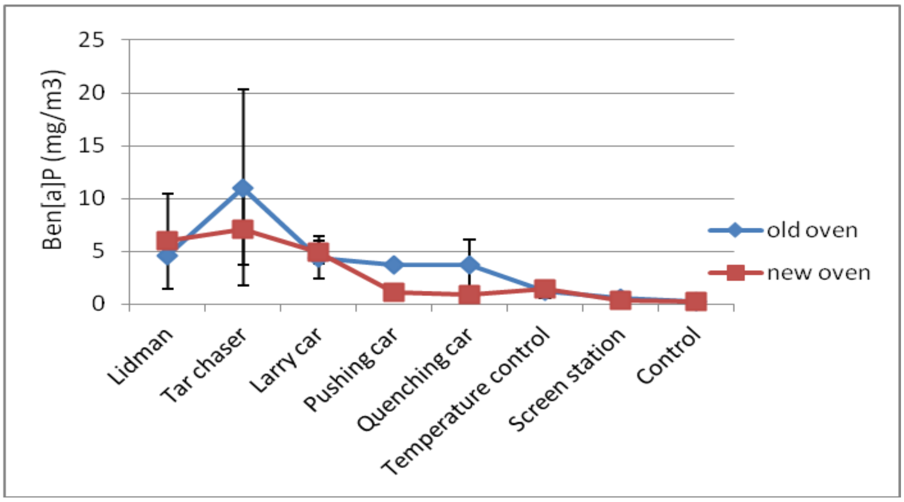

Figure 4.13 Ben[a]P exposure levels for both new and old coke oven workers associated with different job roles

4.5 Comparison of coke oven side workers' exposure level difference between new and old coke oven associated with pushing and quenching job roles

The job role has a direct effect on the coke oven workers' PAH exposure levels. In this analysis, the coke oven workers' PAH exposure level differences were associated with the different job roles. In the previous analysis, it was found out that the PAHs exposure levels display a statistical significant mean difference between the old coke oven side workers and new coke oven side workers. The pushing car drivers and quenching car drivers for both new and old coke oven were included in this analysis.

4.5.1 Comparison of pushing car workers' PAHs exposure level for new and old coke oven

This analysis included 3 pushing car drivers from old coke oven and 9 pushing car drivers from old coke oven.

The PAHs exposure level means for pushing car drivers for both old and new coke ovens, which was summarized in Table 4.13. The mean difference and statistical significant P-value were summarized in Table 4.14.

Table-1 Group Statistics					
	Pushing car drivers	N	Mean (mg/m³)	Std. Deviation	Std. Error Mean
Nap	Old coke oven	3	50.74463	7.3160126	4.2239018
	New coke oven	9	19.78208	7.8597968	2.6199323
Phe	Old coke oven	3	12.97221	7.4570797	4.3053470
	New coke oven	9	4.140385	2.9656035	.9885345
Pyr	Old coke oven	3	3.743971	1.9324534	1.1157025
	New coke oven	9	1.703904	1.5396609	.5132203
Ben[a]P	Old coke oven	3	3.569469	.2478900	.1431194
	New coke oven	9	1.104036	.5842230	.1947410

Table 4.13 The PAH exposure level means for pushing car drivers for both old and new coke ovens

		Levene's Test for Equality of Variances		t-test for Equality of Means					
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
								Lower	Upper
Nap	Equal variances assumed	.047	.832	5.990	10	**.000**	30.9625454	19.4444172	42.4806735
	Equal variances not assumed			6.229	3.698	**.004**	30.9625454	16.7064802	45.2186105
Phe	Equal variances assumed	6.640	.058	3.109	10	**.011**	8.8318236	2.5021921	15.1614551
	Equal variances not assumed			1.999	2.215	**.171**	8.8318236	-8.5123705	26.1760177
Pyr	Equal variances assumed	.581	.464	1.882	10	**.049**	2.0400668	1.3749816	4.4551153
	Equal variances not assumed			1.661	2.903	**.198**	2.0400668	-1.9428124	6.0229461

Ben[a]P	**Equal variances assumed**	.531	.483	6.923	10	**.000**	2.4654336	1.6719560	3.2589113
	Equal variances not assumed			10.201	8.757	**.000**	2.4654336	1.9164044	3.0144628

Table 4.14 Independent sample T-test mean difference and statistical significant P-value

The results of Levene's test were as follows: Nap P=0.832>0.05, Phe P=0.058>0.05 Pyr P=0.464>0.05 and Ben[a]P P=0.483>0.05, therefore the equal variances assumed was found for Nap, Phe, Pyr and Ben[a]P. The T-test for equality of means: Nap P=0.000<0.05, Phe P=0.004<0.05, Pyr P=0.004<0.05 and Ben[a]P P=0.004<0.05. Therefore, the analysis showed a statistical significant difference between the old coke oven side workers and the new coke oven side workers associated with Nap, Phe, Pyr and Ben[a]P. This means that the null hypothesis of no difference between the two measurements was rejected.

Figures 4.14 showed PAH exposure levels for pushing car drivers for both the new and old coke ovens associated with the different job roles.

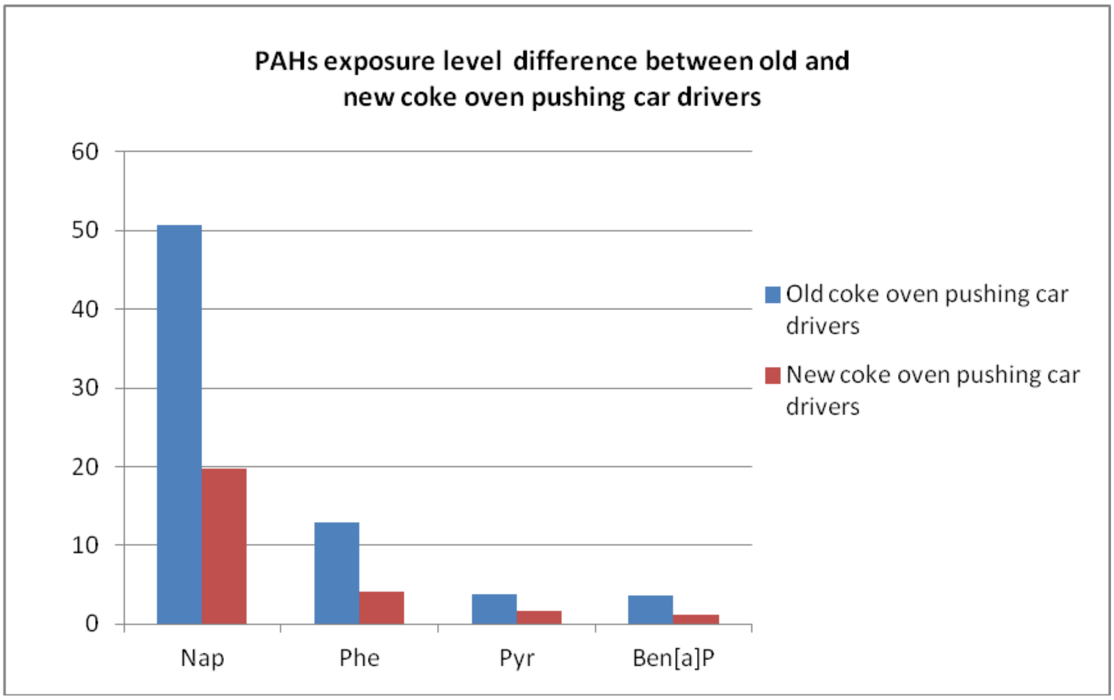

Figure 4.14 PAH exposure levels for pushing car drivers for both new and old coke oven associated with different job roles.

4.5.2 Comparison of quenching car workers' PAHs exposure level for new and old coke oven

This analysis included 6 quenching car drivers from the old coke oven and 6 pushing car drivers from the new coke oven.

The PAHs exposure level means for quenching car drivers for both old and new coke ovens, which is summarized in Table 4.15. The mean difference and statistical significant P-value are summarized in Table 4.16.

Group Statistics					
	Quenching car drivers	N	Mean (mg/m³)	Std. Deviation	Std. Error Mean
Nap	old	6	68.71224	17.5965720	7.1837704
	new	6	19.42651	9.1513694	3.7360309
Phe	old	6	11.47487	6.5424686	2.6709516
	new	6	2.723778	1.5233214	.6218934
Pyr	old	6	3.881680	2.2835571	.9322583
	new	6	.893282	.2544890	.1038947
Ben[a]P	old	6	3.752814	2.3642279	.9651920
	new	6	.854375	.3408510	.1391519

Table 4.15 The PAH exposure level mean for quenching car drivers for both old and new coke ovens

	Levene's Test for Equality of Variances		t-test for Equality of Means					
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
							Lower	Upper

Nap	**Equal variances assumed**	1.421	.261	6.087	10	**.000**	49.2857338	31.2440704	67.3273972
	Equal variances not assumed			6.087	7.520	**.000**	49.2857338	30.4042225	68.1672451
Phe	**Equal variances assumed**	17.323	.002	3.191	10	**.010**	8.7510914	2.6406531	14.8615297
	Equal variances not assumed			3.191	5.541	**.021**	8.7510914	1.9034628	15.5987199
Pyr	**Equal variances assumed**	19.062	.001	3.186	10	**.010**	2.9883979	.8983376	5.0784582
	Equal variances not assumed			3.186	5.124	**.024**	2.9883979	.5945862	5.3822096
Ben[a]P	**Equal variances assumed**	7.459	.021	2.972	10	**.014**	2.8984391	.7256223	5.0712559
	Equal variances not assumed			2.972	5.208	**.030**	2.8984391	.4214646	5.3754136

Table 4.16 Independent sample T-test mean difference and statistical significant P-value

Results for Levene's test are as follows: Nap P=0.261>0.05, therefore the equal variances not assumed was found for Nap. Phe P=0.002<0.05, Pyr P=0.001<0.05 and Ben[a]P P=0.021<0.05. The equal variances not assumed was found for Phe, Pyr and Ben[a]P. The T-test for equality of means were: Nap P=0.000<0.05, Phe P=0.021<0.05, Pyr P=0.024<0.05 and Ben[a]P P=0.030<0.05. Therefore, the analysis showed a statistical significant difference between the old coke oven quenching car drivers and the new coke oven quenching car drivers associated with Nap, Phe, Pyr and Ben[a]P. This means that the null hypothesis of no difference between the two measurements was rejected.

Figures 4.15 showed PAH exposure levels for quenching car drivers for both new and old coke oven associated with different job roles.

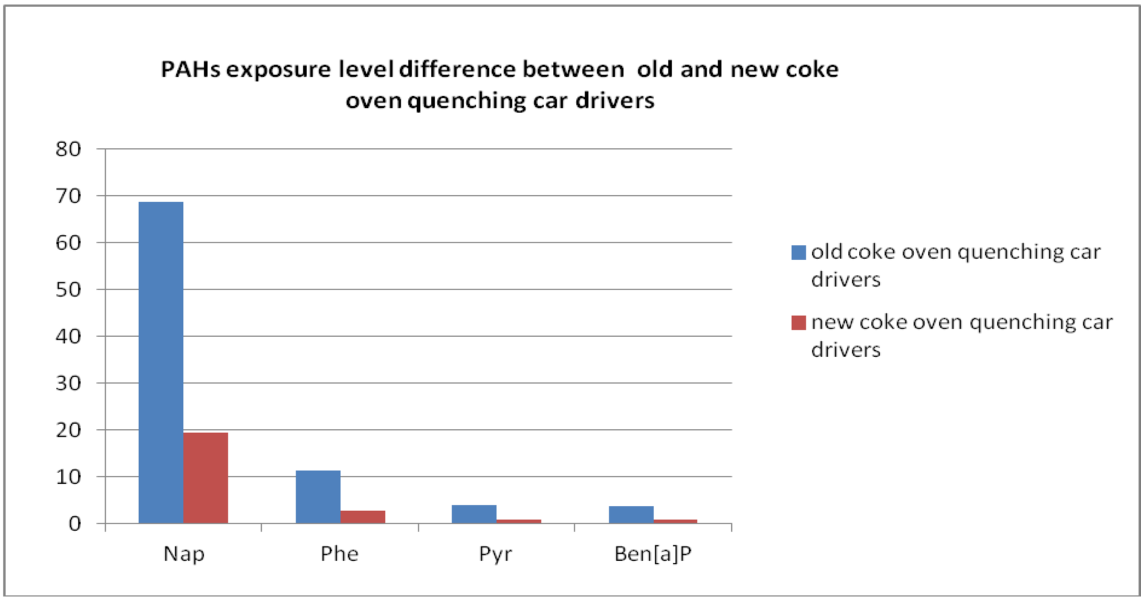

Figure 4.15 PAH exposure levels for quenching car drivers for both new and old coke oven associated with different job roles

4.5.3 Discussion

For pushing car drivers and quenching car drivers, the old coke oven workers' PAH exposure levels were higher than that of the new coke oven workers, probably because the new coke oven has advanced technology on the quenching car and pushing such as a closed compartment with a proper ventilation system, air conditioning and insulated driving cabin which can protect workers from outside gaseous exposures. In the old coke oven, the quenching car and pushing car were designed with an open roof driving cabin, so that workers can only wear personal protective gear to protect themselves against gaseous exposures. The old coke oven pushing car drivers and quenching car drivers have to leave the car during pushing and quenching operations and they can only be protected by standing away from the exposure sources. The PAHs concentrations achieve the highest levels at the moment of pushing and quenching operations. Therefore, the old coke oven pushing and quenching car drivers could be exposed to very high PAHs exposure levels without protection.

4.6 Description of PAHs exposure difference associated with employment period for both new and old coke oven workers

In this analysis, we attempted to find out if there are still other factors that can affect PAH exposure levels for coke oven workers. One such variable investigated was employment period. The coke oven side workers were selected for this analysis, and included the quenching car drivers and pushing car drivers. As described above, the quenching car drivers showed similar PAH exposure level to the pushing car drivers. In this analysis, coke oven side workers worked in the same working condition for each oven. It was hypothesised that the coke oven side workers had different levels associated with the number of years employment and that the latter would have an influence on the individual exposure levels.

This study showed that new coke oven side workers and old coke oven side workers presented statistically significant different PAH exposure levels ($P \leq 0.05$). The analysis has shown that the old workers were exposed to higher levels of PAHs than the new workers.

4.6.1 Evaluate the relationship between PAH exposure level and employment period for old coke oven side workers

The analysis included 4 workers employment period>15 years (called: Group A) and 5 workers employment period<15 years (called: Group B).

In this analysis, the independent sample T-test was used to analyse the data. The P-value was set at a 0.05 significance level that represents a 95% confidence. The PAH exposure level means associated with employment period for old coke oven side workers were summarized in Table 4.17. The mean difference and statistical significant P-value were summarized in Table 4.18.

	Employment Period	N	Mean (mg/m^3)	Std. Deviation	Std. Error Mean
Nap	**>15 years**	4	65.33315	25.2229899	12.6114950
	15> years	5	53.04552	11.5773910	5.1775666

Phe	>15 years	4	18.15777	3.4509387	1.7254693
	15> years	5	8.549630	4.6573964	2.0828510
Pyr	>15 years	4	5.822052	1.1917088	.5958544
	15> years	5	2.702275	1.1596331	.5186037
Ben[a]P	>15 years	4	5.090551	1.6727054	.8363527
	15> years	5	2.960820	1.6951252	.7580830

Table 4.17 Description of PAH exposure level means associate with employment period for old oven side workers

		Levene's Test for Equality of Variances		t-test for Equality of Means			
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference
Nap	**Equal variances assumed**	3.971	.087	2.180	7	**.036**	12.2876317
	Equal variances not assumed			2.101	4.011	**.048**	12.2876317
Phe	**Equal variances assumed**	.014	.909	3.424	7	**.011**	9.6081414
	Equal variances not assumed			3.552	6.987	**.009**	9.6081414
Pyr	**Equal variances assumed**	.002	.962	3.963	7	**.005**	3.1197769
	Equal variances not assumed			3.949	6.478	**.006**	3.1197769
Ben[a]P	**Equal variances assumed**	.005	.945	2.884	7	**.017**	2.1297307
	Equal variances not assumed			2.987	6.609	**.014**	2.1297307

Table 4.18 Independent sample T-test

Levene's test results shows: Nap P=0.087>0.05, Phe P=0.909>0.05, Pyr P=0.962>0.05 and Ben[a]P P=0.945>0.05, therefore the equal variances assumed was found for Nap, Phe, Pyr and Ben[a]P. The T-test for equality of means: Nap P=0.036<0.05, Phe P=0.011< 0.05, Pyr P=0.005 < 0.05 and Ben[a]P P=0.017 < 0.05. Therefore, the analysis showed that were statistical significant difference between employment period >15 year workers (Group A) and employment period<15 years workers (Group B) associated with Nap, Phe, Pyr and Ben[a]P for old coke oven, which means the null hypothesis of no difference between the two measurements was rejected.

4.6.1.1 Discussion

Figures 1-4 present the PAH exposure level means associate with employment period for the old oven side workers. For Nap, Phe, Pyr and Ben[a]P, the exposure level means present Group A> Group B.

The old coke oven side workers mostly worked in the pushing car and quenching cars. The old coke oven quenching car and pushing car were designed with an open roof driver cabin and without other isolation or protective equipment. Therefore, the PAH exposure levels for the old coke oven workers can only be controlled by staying as far as possible of the PAH exposure resource during the pushing and quenching process. The working habit for Group A and Group B workers were observed in the old coke oven side during the times that the personal air samples were taken. It was found that Group B workers (employment period <15) had better working habits than Group A workers (employment period >15) in that Group B workers took their breaks in the restroom or outside of coke oven area, and followed the correct prescribed safety operational steps, which were to leave the pushing car and quenching car and stay far away from PAH exposure source during the pushing and quenching processes. The good working habits may be the reason why reduced Group B workers presented significant lower PAH exposure levels than Group A workers for an average 8 hours working shift. The observation was made that Group A workers had less awareness of protecting themselves against PAHs as Group A workers always took a break in the coke oven working area and some of them were observed even to ate their lunch in the working area. Old coke oven Group B workers did not perform the normative safety operational steps properly as they stayed in the driver room or close to the PAH exposure resource during breaks. Therefore, the Group B workers were exposed to extreme high levels of PAH exposure during pushing and quenching process. Figures 4.16-4.19 showed different PAH exposure levels between Group A workers (employment period >15 years) and Group B workers (employment period < 15years) in the old coke oven site.

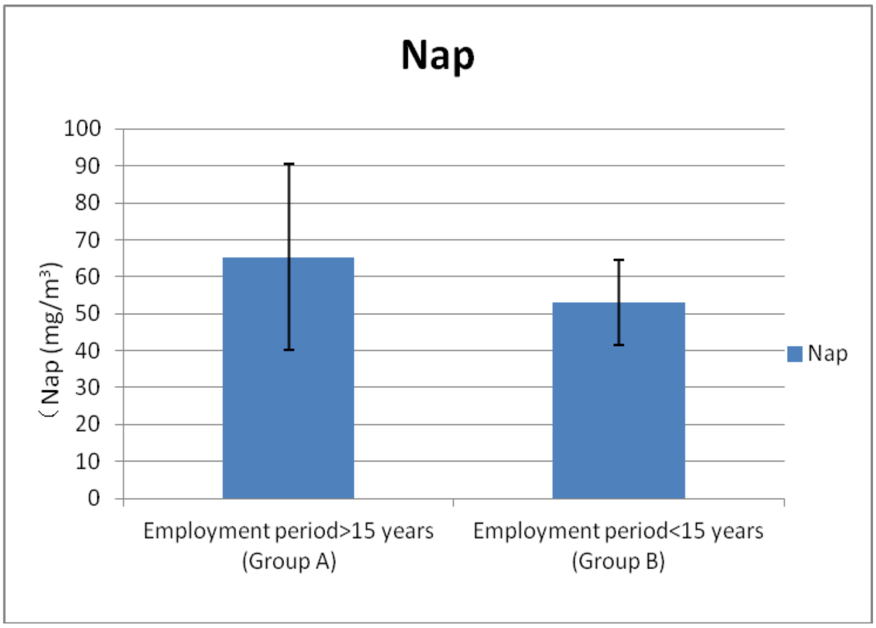

Figure 4.16 Different Nap exposure levels between Group A workers (employment period >15 years) and Group B workers (employment period < 15years) in old coke oven side.

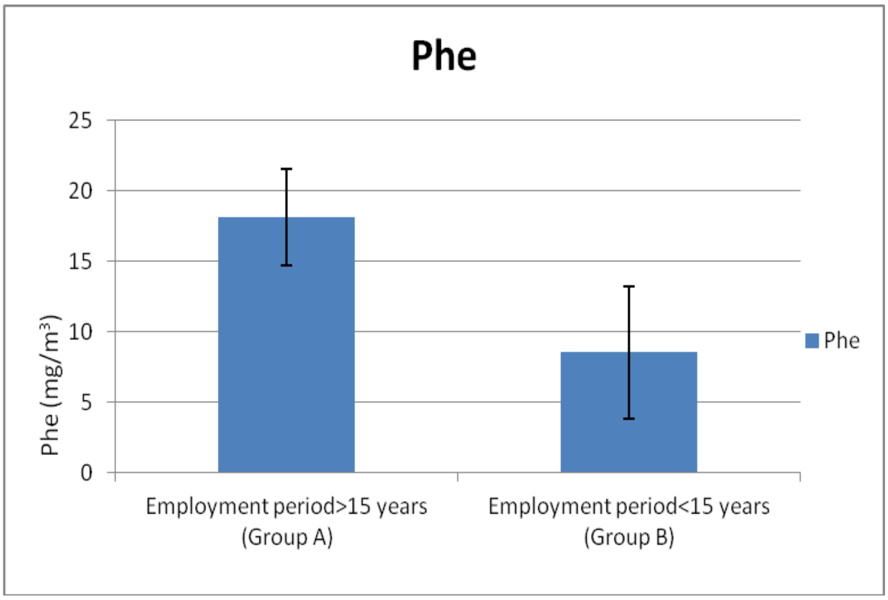

Figure 4.17 Different Phe exposure levels between Group A workers (employment period >15 years) and Group B workers (employment period < 15years) in old coke oven side.

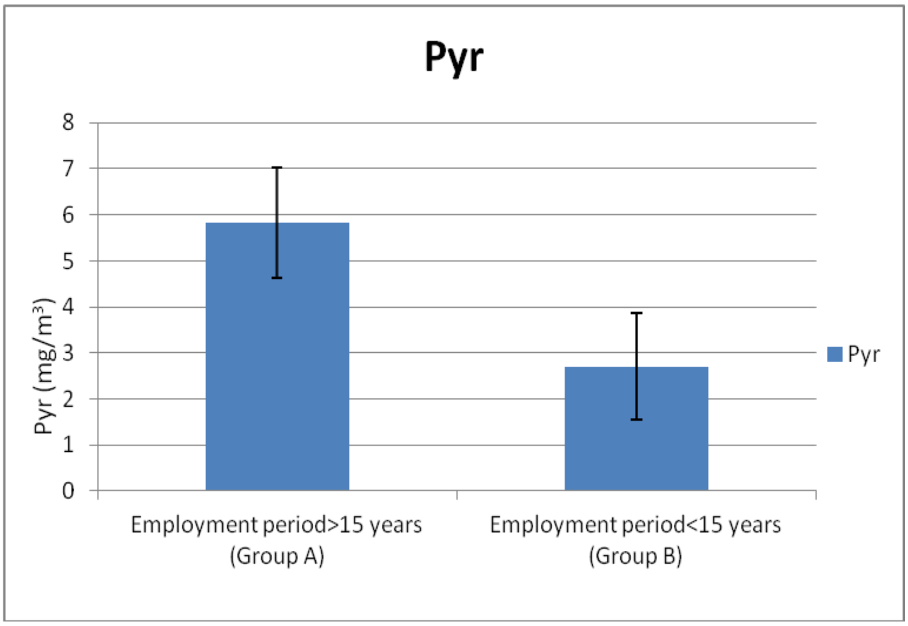

Figure 4.18 Different Pyr exposure levels between Group A workers (employment period >15 years) and Group B workers (employment period < 15years) in old coke oven side.

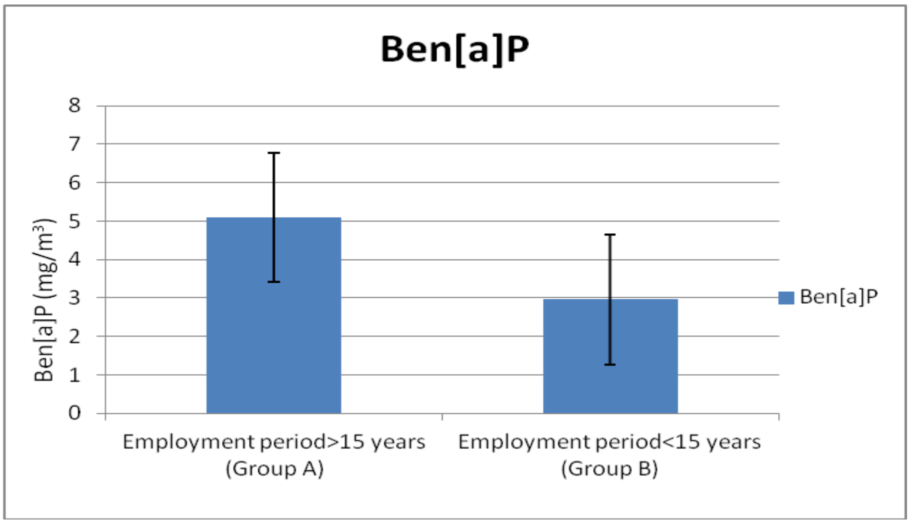

Figure 4.19 Different Ben[a]P exposure levels between Group A workers (employment period >15 years) and Group B workers (employment period < 15years) in old coke oven side.

4.6.2 Evaluate the relationship between PAH exposure level and employment period for new coke oven side workers

The exposure level means for new oven side workers associate with employment period is summarized in Table 1. The analysis included 7 workers employment period>15 years (called: group A) and 8 workers employment period<15 years (called: group B).

In this analysis, the independent sample T-test to analyse the data were used. The P-value was set at a 0.05 significance level that represents a 95% confidence. The PAH exposure level means associated with employment period for new coke oven side workers were summarized in Table 4.19. The mean difference and statistical significant P-value were summarized in Table 4.20.

	Employment period	N	Mean (mg/m^3)	Std. Deviation	Std. Error Mean
Nap	**>15 years**	7	22.2243	9.41287	3.55773
	<15 years	8	17.3785	6.48213	2.29178
Phe	**>15 years**	7	4.8566	3.20598	1.21175
	<15 years	8	2.4512	.91915	.32497
Pyr	**>15 years**	7	1.8557	1.73468	.65565
	<15 years	8	.9632	.29888	.10567
Ben[a]P	**>15 years**	7	1.2587	.62641	.23676
	<15 years	8	.7815	.21754	.07691

Table 4.19 Description of PAH exposure level means associate with employment period for new oven side workers

		Levene's Test for Equality of Variances		t-test for Equality of Means					
								95% Confidence Interval of the Difference	
		F	Sig.			Sig. (2-tailed)	Mean Difference	Lower	Upper
Nap	**Equal variances assumed**	2.237	.159	1.175	13	.261	4.84580	-4.06526	13.75686
	Equal variances not assumed			1.145	10.468	.278	4.84580	-4.52686	14.21846

Phe	**Equal variances assumed**	2.674	.126	2.038	13	.062	2.40543	-.14391	4.95478
	Equal variances not assumed			**t**	**df**	.098	2.40543	-.57313	5.38400
Pyr	**Equal variances assumed**	3.513	.084			.174	.89250	-.44779	2.23278
	Equal variances not assumed			1.344	6.312	.225	.89250	-.71324	2.49824
Ben[a]P	**Equal variances assumed**	2.757	.121	2.029	13	.063	.47722	-.03097	.98541
	Equal variances not assumed			1.917	7.264	.095	.47722	-.10713	1.06156

Table 4.20 Independent sample T-test

Levene's test: Nap P=0.159>0.05, Phe P=0.126>0.05, Pyr P=0.084>0.05 and Ben[a]P P=0.121>0.05, therefore the equal variances assumed was found for Nap, Phe, Pyr and Ben[a]P. T-test for equality of means: Nap P=0.261>0.05, Phe P=0.062>0.05, Pyr P=0.174>0.05 and Ben[a]P P=0.063>0.05, therefore the analysis showed that were statistical non-significant difference between employment period >15 year workers (Group A) and employment period<15 years workers (Group B) associated with Nap, Phe, Pyr and Ben[a]P for new coke oven, which means the null hypothesis of no difference between the two measurements was accepted.

4.6.2.1 Discussion

In the new coke oven, the Group A workers presents some unhealthy working habit, i.e. eating lunch in driver room and taking a break in driver room without go to retiring room. These working habits that cause an increase in PAHs exposure levels could be masked by effective protective equipment in the new coke oven. New coke oven side workers worked in pushing car and quenching car. The pushing car and quenching car had effective equipment and sealed driver room to avoid PAHs exposure. Workers can finish their full working shift by remaining in the driver rooms. Therefore the unhealthy working habit did not provide a significant effect to increase PAHs exposure levels for Group A workers at the new coke oven. The effective protection equipment may be the possible reason why the PAHs exposure levels present a non-significant different between Group A workers and Group B workers in new coke oven.

4.6.3 Summary

In the investigation, the Group B (employment period >15 years) workers presented a worse working habit than that of Group A (employment period < 15 years) workers for both the new and old coke oven. The inspection and management for correct operation step is important to implement, especially for Group B workers. It was also observed that Group B worker had a better performance than Group A workers when it comes to the use PPE. Group A workers had a higher proportion than Group B workers to work in the coke oven area without wearing a respirator. Improve health protective awareness is important to avoid PAH exposure for coke oven workers, especially for Group B workers.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

This chapter summarises the previous chapters that discussed various factors related to PAHs exposure among coke oven workers. On the one hand this thesis focuses on the risk of PAHs exposure among coke oven workers, and on the other hand, it focused upon the possible improvements can still be made to reduce the PAHs exposure related to different working areas associated with in coke ovens. This chapter will first summarise the work and will then address the possible intervention programmes with specific reference to the various working areas associated with a typical coke oven.

As indicated, this work involves the evaluation of PAHs exposure levels to describe the risk for the different groups of workers associated with related PAHs exposure determining factors. The study used the personal air sampling analysis technique that is generally considered to be more efficient and reliable for personal exposure evaluation, easy to operate, and can provide accurate data for each worker.

5.1 Conclusions

This data was analysed with the HAPSITE Smart man portable GC-MS analysis for coke oven working areas in order to verify the exposure of workers to the various PAHs. Four kinds of PAH compound exposures were selected for monitoring in this research, which are Nap, Phe, Pyr and Ben[a]P. The personal air sampling technique was used for personal data collection which measures the exposure of workers at the different positions around the oven as they move around during their daily routine. The data was analysed in a laboratory with an Agilent 6890N Network Gas Chromatograph. A proper risk assessment was calculated for coke oven workers. A further purpose of the project was to investigate the feasibility of control measures for coke oven workers in order to avoid hazardous PAHs exposures.

Chapter two described the key features of coke oven emissions (COE) especially PAHs, and the relationships between PAHs exposure and health. Based on secondary sources, it was indicated that PAHs exposure can have a negative influence on human health, and also that PAHs is a carcinogen and those workers that are exposed to PAHs during working shifts do run a higher risk than the normal person not working in such an environment to get cancer. The advanced HAPSITE Smart and Agilent 6890N Network Gas Chromatograph air sampling analysis principle, method and equipment were described, and the coking procedures and coke oven worker job roles were discussed in this chapter.

Chapter three concentrated on the research design and the data collection and data analysis techniques were discussed. The data collection technique was used the personal air sampling technique in order to collect air samples during a full eight hour working shift. The Agilent 6890N Network Gas Chromatograph operation data analysis technique was described. The advance settings of the equipment and program used to do the analysis were described. The data was collection and analysis was done according to the prescribed NIOSH 5515 protocol.

Chapter four explored the relationship between PAHs exposure levels and selected independent variables such as coke oven position, coke oven job roles, coke oven technique and years working experience. It was found that the PAHs exposure level difference between the control group and the two coke ovens' workers were statistical significant, with the control group (administrative workers) showing no exposure to PAHs compared with the coke oven workers. The PAH exposure levels also showed a statistical significant difference among the different job roles. In this chapter, it was found, that the old coke oven workers were exposed to higher levels of PAHs than the new coke oven workers. The workers with a low education also measured a higher PAHs exposure level than the workers with a higher education. The PAHs exposure difference for each particular groups associate with Nap, Phe, Pyr and Ben[a]P were also measured and showed statistical significant differences.

5.2 Recommendations

It is clear that control measures are important to be implemented in coke oven area to protect workers from excessive PAHs exposures. The authorities should supervise the management of the control measures that are in place and for monitoring purposes, physical examinations should be performed at least annually on coke oven workers. The results of the inspection and evaluation of PAHs exposure levels among coke oven workers in the work place should be reported to the supervisor with a proper risk assessment report. As a result of this research, the following control measures are recommended to reduce coke ovens workers' risk to excessive levels of PAHs exposure. (Lave, L. & Leonard, B. 1988: 560)

5.2.1 Engineering controls

The study showed that the old coke oven workers were exposed to higher PAH levels than new coke oven workers, especially for old coke oven side workers. It is clear that the outdated equipment is the most possible reason for this observation and that to update the old coke oven equipment could possibly be an effective measure to reduce PAH exposure levels for workers in the old coke oven. (OAR 437)

The sealed driver room should be applied to quenching car and pushing car for old coke oven and the ventilation system and air conditioning should be installed in both the quenching and pushing cars. Renewal of the equipment and operating techniques should also directly reduce exposure levels for coke oven side workers. (WHO, 1987)

For coke oven top workers, observations revealed that some lids and pipes leaked and were broken and not repaired and replaced, especially in the old coke oven top. This cannot be accepted and is clearly a management issue that neglect basic safety rules that are in place. Regular inspections of all controls, including goosenecks, standpipes, standpipe caps, charging hold lids and castings, jumper pipes and air seals for cracks are clearly necessary for both new and old coke ovens and reparation must be implemented as soon as possible after discovery thereof. The larry car in the old coke oven should be inspected more often than new coke oven larry car and after inspection, it is suggested that the ventilation system should be renewed in the old coke oven larry car.

The coking techniques are also important for reducing PAH levels in the coke oven working area. Proper management is needed to do control checks on the oven pressure to maintain uniform pressure conditions in the collecting main which is important for COE control during coking procedures, and the leaking oven doors must be repaired, replaced or adjusted to avoid leaks in order to reduce the exposure of workers to excessive PAH levels in the coke oven side working area for both new and old coke ovens (World Bank, 1995).

It is clear from the aforementioned that engineering control measures can improve working conditions for coke oven workers directly and that it could be seen as an effective method to reduce PAH levels to coke oven workers (OAR 437).

5.2.2 Practice and training

Coke oven workers must have formal safe working practices and training before they start to work in the coke oven area. The information for chemical hazards and protective system must be provided to workers, especially to the old coke oven workers due to their higher measured exposure to coke oven emission levels. Interviews with the workers revealed inadequate training that resulted in workers being ignorant of the dangers involved in the exposure to high levels of PAHs in the different working areas (Council on Wage and Price Stability. 1976: 44-49).

5.2.2.1 Training program

Training should be provided that includes such information as the purpose, proper use, and limitations of respiratory protective devices; the purpose for and a description of the medical surveillance program including information on the occupational safety and health hazards associated with exposure to coke oven emissions. The information must especially be provided to old coke oven workers, which is working at old coke oven expose to higher PAH exposure levels than new coke oven. Observations regarding the working habits of the workers and during informal discussions with the workers, it was clear that the most basic knowledge in this regard was lacking.

Food or beverages are prohibited to be present in the coke oven working area, smoking products are not allowed to present or used in working area, except that these activities may be conducted in the lunchrooms and change rooms. More attention must be applied to these issues, especially to workers with a low education level as was discussed in chapter four. During inspection it seemed that the workers were either ignorant or did not know what the basic management procedures are regarding the use of food, beverages or smoking habits are when working in the coke over area (OAR 437).

5.2.2.2 Practical program

Work practice control measures are important for both new and old coke ovens workers. The correct manipulation and proper management for each coke-making step can reduce coke oven emission levels. The low education level workers should be acknowledged and accommodated in the training process to make sure that all workers follow the normative steps during the coke making procedure.

It is suggested that new workers should undergo practical sessions before they start to work independently. The larry car drivers, pushing car drivers and quenching car drivers have shown the most exposure to PAHs and should be duly trained under supervision to operate the equipment before they work independently. The information of operation steps is referenced in Appendix. A.

5.2.3 Respiratory protection

The respiratory protective equipment is the easiest method to implement in coke oven area to control COE exposure level for coke oven workers and coke oven workers simply must wear proper respiratory protective equipment in coke oven area. During the data collection process, it was observed that it was not the case. The performance for workers in the old coke oven clearly need more attention, because the workers in the old coke oven still used equipment that is out dated and that provides less protection to avoid coke oven emissions. I.e. the respiratory protection equipment for coke oven workers should be replaced at least quarterly (OAR 437).

5.2.4 Protective clothing and equipment

Protective clothing and equipment are required as a general outfit for workers working in the coke oven area. All persons entering the coke oven area should wear protective clothing. The appropriate protective clothing and equipment should be provided and assured, such as flame resistant jacket and pants; flame resistant gloves; face shields or vented goggles; footwear providing insulation from hot surfaces; safety shoes; protective helmets. During the data collection process of this study, it was observed that the protective clothing mentioned above was not worn at the old coke oven, and only in some cases in the new oven. It seems that a general lack in safety management could be the reason for this (OAR 437).

5.2.5 Hygiene facilities and practices

Proper hygiene facilities with proper ventilation system and air conditioning are needed in any coke oven. During this research it was found that especially for old coke oven, the ventilation system should be re-evaluated and if necessary replaced or improved at the old coke oven as the equipment is outdated compared to the new coke oven.

The change room was not provided in the old coke oven and workers used the restroom to change their clothes. Clean changing rooms, equipped with storage facilities is suggested to provide the workers with facilities to store their street clothes in separate facilities than that is used for protective clothing and equipment in old coke oven area.

In order to avoid exposure to COE, shower facilities should be provided for both new and old coke ovens that is located outside of coke oven working area.

Because the lunchroom is far for both new and old coke ovens, some workers have lunch in the coke oven working area. To overcome this practice, lunchroom facilities should be ameliorated which has a temperature controlled, positive pressure, filtered air supply, and which are readily accessible to employees working in the regulated area (OAR 437).

5.2.6 Medical surveillance

As workers in both the old and new coke ovens showed excessive exposure to PAHs, medical surveillance is important to detect the effect thereof on the workers. At both new and old coke ovens. It is known that proper medical surveillance can protect health effects for coke oven workers.

Such medical examinations should be performed by a licensed physician, and be provided without cost to the employee. The medical examination provided for coke oven workers should, include pulmonary function tests; a skin examination; urinalysis for sugar, albumin, and hematuria; a sputum cytology examination and a urinary cytology examination.

The examinations should be provided at least annually for employees. Because of the higher exposure to PAHs in the old coke oven, it is suggested that the old coke oven workers should have more regular medical examinations than the new coke oven workers, i.e. an examination every half-year, instead of once a year, which is prescribed by law and currently in place. In addition, it is suggested that the workers with over 15 years working experience should have an examination every half-year. (OAR 437)

This recommendation provided some additional procedures to help to eliminate excessive exposure to PAHs among coke oven workers and is an effort to establish an improved coke oven emission control measures given the working conditions for especially workers in similar environments as the old coke oven that were part of this study. Following this procedures the coke oven workers could be exposed to reduced levels of COE and the PAH health effects on coke oven workers could be controlled effectively. More information of COE control management is referenced in Appendix. B.

Reference

1. Adlard, E.R., Handley, A.J. 2001. *Gas chromatographic techniques and applications*. London: Sheffield Academic.
2. Agilent Technologies, Inc. 2002. Agilent 6890N Network Gas Chromatograph Specifications. http://www.chem.agilent.com/Library/specifications/Public/5988-5329EN.pdf
3. Anon. 1999. Diesel emission and lung cancer. Epidemiology and Quantitative.
4. Association of Iron and Steel Engineers. 1985. The Making, Shaping, and Treating of Steel, 10th Edition,
5. Association of Iron and Steel Engineers. 1985.The Making, Shaping, and Treating of Steel, 10th Edition. http://www.energysolutionscenter.org/heattreat/MetalsAdvisor/iron_and_steel/process_descriptions/raw_metals_preparation/coking/coking_process_description.htm
6. Bertrand, J.P., Chau, N., Patris, A. et al. 1987. Mortality due to respiratory cancers in the coke oven plants of the Lorraine coal mining industry Houilleres due Bassin de Lorraine. Br. J. Ind. Med.
7. Bhowmik, B. 2009. Instrumentation for coking process management in a coke oven battery, Steel Times International.
8. Camp, J. M. 1985.The Making, Shaping, and Treating of Steel, 10th Edition. Association of Iron and Steel Engineers.
9. Chen M.L., Mao, I.F., Wu, M.T., Chen, J.R., Ho, C.K., Smith, T.J., Wypij, D., Christiani D.C. 1999. Assessment of Coke Oven Emissions Exposure among Coking Workers. Am. Ind. Hyg. Assoc. J. Vol. 60, No.
10. Council on Wage and Price Stability. 1976. Exposures to Coke Oven Emissions: Proposed Standard, Executive Office of the President.
11. Dong, Redmond, Mazumdar & Costantino. 1988. A Multistage Approach to the Cohort Analysis of Lifetime Lung Cancer Risk Among Steelworkers Exposed to Coke Oven Emissions. 128 AM. J. Epidemiology 860.
12. EPA (Environmental Protection Agency) 1984, U.S. Carcinogen Assessment of Coke Oven Emissions, Final Report of OHEA.

13. EPA (Environmental Protection Agency). 1987. U.S. Coke Oven Emissions from Wet-Coal Charged By-Product Coke Oven Batteries: Background Information for Proposed Standards.
14. Fetzer, J.C. 2000. The Chemistry and Analysis of the Large Polycyclic Aromatic Hydrocarbons. Polycyclic Aromatic Compounds (New York: Wiley).
15. Glenn, M.R. 1995. Activated carbon applications in the food and pharmaceutical industries. CRC Press. p.125. http://books.google.com/books?id=nmmpK0oDE20C&pg=PA125.
16. Graham, J.D. 1989. Coke Oven Emissions: A Case Study of Technology-Based Regulation.
17. HAPSITE® Smart Chemical Identification System, INFICON 2004. www.inficon.com
18. HAPSITE® Smart. 2004. Chemical identification system. http://www.inficon.com/download/en/haps-smart.pdf.
19. Harris, D.C. 1999. Gas Chromatography, Quantitative chemical analysis Fifth ed, W. H. Freeman and Company.
20. Hu, Y. 2000. Department of Occupational and Environmental Health. School of Public Health, Fudan University, Shanghai, China.
21. IARC (International Agency for Research on Cancer). 1984. Polynuclear Aromatic Compounds, Part 3. Industrial Exposures in Aluminum Production, Coal Gasification, Coke Production, and Iron and Steel Founding. IARC Monographs on the Evaluation of Carcinogenic Risk of Chemicals to Humans, vol. 34. Lyon, France: International Agency for Research on Cancer.
22. IARC (International Agency for Research on Cancer). 1987. Overall Evaluations of Carcinogenicity. IARC Monographs on the Evaluation of Carcinogenic Risk of Chemicals to Humans, Supplement 7. Lyon, France: International Agency for Research on Cancer.
23. IARC (World Health Organization, International Agency for Research on Cancer). 1987. Monograph on the Evaluation of Carcinogenic Risks to Humans Supplements 7.
24. Inayama. 2003. Automation Techniques of Coke Oven Moving Machines.
25. Jones, A. 2004.Current coke market developments. In: IPIS meeting. Dusseldorf.
26. Lamm, S.H. 1983. Consultants in Epidemiology and Occupational Health, Inc., to Thorslund, T. EPA. Critique of EPA's risk assessment of coke oven emissions.

27. Larsson, B.K., Sahlberg, G.P., Eriksson, A.T., Busk, L.A. 1983. Polycyclic aromatic hydrocarbons in grilled food. J Agric Food Chem.

28. Lave, L. & Leonard, B. 1988 Regulating Coke Oven Emissions in Risk Assessment of Environmental and Human Health Hazards: A text book of case studies 560.

29. Lloyd, J.W. 1971. Long-term mortality study of steelworkers. V. Respiratory cancer in coke plant workers. J. Occupational Medicine.

30. Luch, A. 2005. The Carcinogenic Effects of Polycyclic Aromatic Hydrocarbons. London: Imperial College Press.

31. Martinez, Z. 2009. Method for the Direct Reduction of Iron Oxides to Metallic Iron Utilizing Coke Oven Gas or the like.

32. McLafferty, G.R., Fred, W. 1993. Early gas chromatography/mass spectrometry. Journal of the American Society for Mass Spectrometry.

33. McNeil & William, H. 1982. The Pursuit of Power. University of Chicago Press.

34. Mulas, G. 2006. Estimated IR and phosphorescence emission fluxes for specific polycyclic aromatic hydrocarbons in the Red Rectangle. Astronomy and Astrophysics.

35. NIOSH 5515. 1994. Polynuclear Aromatic Hydrocarbons by GC: Method 5515, Issue 2.

36. OAR (General occupational safety and health rules) 437, Division 2, subdivision Z – Toxic and Hazardous Substances Coke Oven Emissions.

37. OAR 437, Division 2 General Occupational Safety and Health Rules Subdivision Z – Toxic and Hazardous Substances.

38. Pavia, D.L., Gary M. Lampman, G,M., S. Kritz, S., Engel, R.G. 2006. Introduction to Organic Laboratory Techniques (4th Ed.). Thomson Brooks/Cole.

39. Polenske, K.R. 2002. A Chinese coke making process-flow model for energy and environmental analyses.

40. Polycyclic Aromatic Hydrocarbons (PAHs). Agency for Toxic Substances and Disease Registry. 1996. http://www.atsdr.cdc.gov/tfacts69.html#bookmark02.

41. Sakabe, H., Tsuchiya, K., Tahekura N. 1975. Lung cancer among coke oven workers. A report to Labour Standard Bureau, Ministry of Labour, Japan. Ind. Health.

42. Sax, N.I. 1987. Hawley's Condensed Chemical Dictionary 11th Edition. New York: Van Nostrand Reinhold Corporation.

43. Sengupta, B. 2003. Polycyclic Aromatic Hydrocarbons (PAHs) In Air and Their Effects On Human Health. http://www.cpcb.nic.in/
44. Stellman, J.M. 1998. Encyclopaedia of occupational health and safety. Fourth Edition,
45. Stephen, M.R. 2008. Quantitative Exposure Assessment. University of California.
46. Toll, H. 2000. The CSQ coke stabilization quenching process.
47. U.S. Dept. of Labour, Exposure to Coke Ovens, 41 Fed. Reg. 46,748. 1976. For an overview of the limited literature on non-malignant respiratory effects.
48. U.S. Environmental Protection Agency [hereafter EPA]. 1984. Carcinogen Assessment of Coke Oven Emissions, Final Report of OHEA.
49. U.S. Environmental Protection Agency [hereafter EPA]. 2001. Carcinogen Assessment of Coke Oven Emissions, Final Report of OHEA.
50. U.S. Environmental Protection Agency. 1999. Integrated Risk Information System (IRIS) on Coke Oven Emissions. National Center for Environmental Assessment, Office of Research and Development, Washington, DC.
51. United Mine & Coke Works, United, Mt. Pleasant Twp., Westmoreland County, PA, USA http://patheoldminer.rootsweb.ancestry.com/united.html
52. WHO (World Health Organization). 1989. Management and Control of the Environment. WHO/PEP/89.1. Geneva.
53. World Bank. 1995. Industrial Pollution Prevention and Abatement: Coke Manufacturing. Draft Technical Background Document. Washington, D.C.
54. Yang, L. 2002. Multi-Field Coupled Numerical Simulation of Dry Distillation Gas Seepage Moving in the Process of Underground Coal Gasification. Journal of Xi'an Jiaotong University. Issue 7.

APPENDIX

Table of data analyse and calculation result by Gas Chromatograph

Nap µg/ml (filter)	Nap µg/ml (tubes)	tube (µg/ml) section A	tube (µg/ml) section B	Percentage (section B /section A)
459.64	5220.85	4928.4824	292.3676	0.059322
401.49	3629.3	3382.5076	246.7924	0.0729614
472.38	2095.02	2000.7441	94.2759	0.0471204
393.11	6523.05	6275.1741	247.8759	0.039501
485.98	2754.12	2544.8069	209.31312	0.0822511
480.21	2813.27	2574.1421	239.12795	0.0928962
439.28	2431.64	2336.806	94.83396	0.0405827
528.4	7236.61	6607.0249	629.58507	0.0952903
549.6	9470.35	8750.6034	719.7466	0.0822511
480.14	17448.58	16506.357	942.22332	0.0570825
447.96	3062.58	2835.9491	226.63092	0.0799136
449.36	2887.62	2708.5876	179.03244	0.0660981
429.18	7978.64	7635.5585	343.08152	0.0449321
511.84	11556.38	10782.103	774.27746	0.0718114
416.53	15817.99	14963.819	854.17146	0.0570825
410	37305.7	34507.773	2797.9275	0.0810811
290.76	6015.24	5528.0056	487.23444	0.0881393
436.22	2269.48	2101.5385	167.94152	0.0799136
365.5	11681.44	10910.465	770.97504	0.0706638

426.08	5147.31	4802.4402	344.86977	0.0718114
405.63	2123.56	1936.6867	186.87328	0.0964912
447.77	3624.81	3458.0687	166.74126	0.048218
501.34	2798.59	2616.6817	181.90835	0.0695187
483.48	8592.43	7956.5902	635.83982	0.0799136
472.2	13400.59	12368.745	1031.8454	0.0834236
400.93	4403.84	4117.5904	286.2496	0.0695187
480.29	11881.62	10907.327	974.29284	0.0893246
462.6	7064.01	6527.1452	536.86476	0.0822511
464.66	12973.45	12804.795	168.65485	0.0131712
511.1	9338.2	9170.1124	168.0876	0.0183299
501.74	5892.4	5762.7672	129.6328	0.0224949
494.62	6090.71	5828.8095	261.90053	0.0449321
408.4	6674.78	6414.4636	260.31642	0.0405827
415.48	10054.53	9773.0032	281.52684	0.0288066
58.8	15668.75	14618.944	1049.8063	0.0718114
403.49	2011.37	1898.7333	112.63672	0.059322
442.31	4190.36	3876.083	314.277	0.0810811
442.38	5067	4641.372	425.628	0.0917031
303.55	16027.86	15322.634	705.22584	0.0460251
490.41	11578.12	11311.823	266.29676	0.0235415
519.9	11177.04	10964.676	212.36376	0.019368
428.07	1970.87	1842.7635	128.10655	0.0695187
386.6	11199.09	11064.701	134.38908	0.0121457
395.71	13443.91	12610.388	833.52242	0.0660981

455.48	5467.01	5385.0049	82.00515	0.0152284
474.94	3936.18	3672.4559	263.72406	0.0718114
426.89	4086.96	3768.1771	318.78288	0.0845987
383.48	6421.62	6286.766	134.85402	0.0214505
505.43	2110.27	2059.6235	50.64648	0.0245902
450.16	20731.75	19404.918	1326.832	0.0683761
347.33	101.22	100.00536	1.21464	0.0121457
352.1	121.43	119.12283	2.30717	0.019368
364.35	152.7	139.4151	13.2849	0.0952903
357.35	112.79	104.44354	8.34646	0.0799136
326.96	208.99	193.10676	15.88324	0.0822511
470.2	11259.54	10561.449	698.09148	0.0660981
455.18	14309.81	13293.813	1015.9965	0.0764263
490.04	11070.74	10771.83	298.90998	0.0277492
492.6	8505.04	8088.293	416.74696	0.0515247
1	368.5	356.708	11.792	0.0330579
1	210.66	203.49756	7.16244	0.0351967
1.04	456.57	430.08894	26.48106	0.0615711
1.07	399.77	374.18472	25.58528	0.0683761
1	456.7	418.3372	38.3628	0.0917031
1	401.19	391.56144	9.62856	0.0245902
1	156.04	154.63564	1.40436	0.0090817
1	136.15	125.5303	10.6197	0.0845987
1	158.28	147.67524	10.60476	0.0718114
1	183.46	180.89156	2.56844	0.0141988

Phe filter (μg/ml)	Phe tube (μg/ml)	Phe tube section A (μg/ml)	Phe tube section B (μg/ml)	Percentage (section B /section A)
207.77	2323.51	2121.3646	202.14537	0.0952903
139.29	1225.78	1135.0723	90.70772	0.0799136
86.8	243.08	224.60592	18.47408	0.0822511
161.14	2393.93	2245.5063	148.42366	0.0660981
127.09	405.1	395.3776	9.7224	0.0245902
242.67	491.41	478.14193	13.26807	0.0277492
56.63	548.19	499.40109	48.78891	0.0976948
1239.05	1714.1	1659.2488	54.8512	0.0330579
1265.39	2877.84	2779.9934	97.84656	0.0351967
3514.62	329.66	310.53972	19.12028	0.0615711
67.08	809.65	757.8324	51.8176	0.0683761
83.83	468.02	428.70632	39.31368	0.0917031
482.12	3923.41	3829.2482	94.16184	0.0245902
552.98	1738.61	1722.9625	15.64749	0.0090817
42.7	983.8	907.0636	76.7364	0.0845987
1691.1	10254.3	9567.2619	687.0381	0.0718114
1966.37	638.47	629.53142	8.93858	0.0141988
599.97	252.03	230.85948	21.17052	0.0917031
846.1	2980.02	2848.8991	131.12088	0.0460251
91.51	1806.5	1764.9505	41.5495	0.0235415
121.43	309.6	303.7176	5.8824	0.019368
95.86	693.88	648.7778	45.1022	0.0695187
130.05	690.08	681.79904	8.28096	0.0121457

442.89	611.66	573.73708	37.92292	0.0660981
1467.3	5999.43	5909.4386	89.99145	0.0152284
43.69	256.35	239.17455	17.17545	0.0718114
203.82	2905.72	2679.0738	226.64616	0.0845987
434.4	1221.01	1195.3688	25.64121	0.0214505
202.69	722.45	705.1112	17.3388	0.0245902
839.34	2697.73	2546.6571	151.07288	0.059322
135.27	461.21	429.84772	31.36228	0.0729614
56.36	249.3	238.0815	11.2185	0.0471204
802.75	2145.05	2063.5381	81.5119	0.039501
54.27	1992.35	1840.9314	151.4186	0.0822511
1629.09	1693.22	1549.2963	143.9237	0.0928962
41.77	186.9	179.6109	7.2891	0.0405827
95.98	417.15	380.85795	36.29205	0.0952903
170.7	1741.72	1609.3493	132.37072	0.0822511
1248.95	3057.3	2892.2058	165.0942	0.0570825
325.81	1547.49	1432.9757	114.51426	0.0799136
172.4	757.63	691.71619	65.91381	0.0952903
101.13	510.31	471.52644	38.78356	0.0822511
658.35	1070.38	1012.5795	57.80052	0.0570825
44.39	626.7	580.3242	46.3758	0.0799136
78.24	1091.14	1040.9476	50.19244	0.048218
47.8	251.9	241.0683	10.8317	0.0449321
38.11	283.83	264.81339	19.01661	0.0718114
61.9	869.09	822.15914	46.93086	0.0570825

76.51	145.25	134.35625	10.89375	0.0810811
36.28	266.21	244.64699	21.56301	0.0881393
30.59	32.87	30.43762	2.43238	0.0799136
26.68	25.75	24.0505	1.6995	0.0706638
26.25	30.88	28.81104	2.06896	0.0718114
27.23	22.91	20.89392	2.01608	0.0964912
19.3	15.02	14.32908	0.69092	0.048218
968.78	4240.83	3965.1761	275.65395	0.0695187
736.28	4323.96	4267.7485	56.21148	0.0131712
587.44	2974.91	2921.3616	53.54838	0.0183299
325.72	2531.07	2475.3865	55.68354	0.0224949
29.45	10.66	10.20162	0.45838	0.0449321
25.9	14.1	13.5501	0.5499	0.0405827
40.71	11.62	11.29464	0.32536	0.0288066
45.03	10.39	9.69387	0.69613	0.0718114
39.54	12.08	11.52432	0.55568	0.048218
41.48	9.36	8.95752	0.40248	0.0449321
26.62	14.17	13.22061	0.94939	0.0718114
24.85	13.1	12.3926	0.7074	0.0570825
25.86	14.27	13.19975	1.07025	0.0810811
30.25	14.75	13.55525	1.19475	0.0881393

Pyr filter (μg/ml)	Pyr tube (μg/ml)	Pyr tube section A (μg/ml)	Pyr tube section B (μg/ml)	Percentage (section B /section A)
335.29	288.73	277.75826	10.97174	0.039501
243.83	142.55	132.63665	10.8338	0.0816803
101.75	29.46	27.411263	2.5041	0.091353
443.56	161.65	150.40837	6.30435	0.0419149
153.12	31.25	29.076781	2.71875	0.0935024
212.43	24.42	22.72176	1.85592	0.0816803
106.06	37.44	34.83631	2.02176	0.058036
725.33	101.74	94.664695	7.52876	0.0795308
1109.01	32.03	29.802538	1.98586	0.0666339
1262.48	23.05	21.447034	0.99115	0.0462138
135.32	54.86	51.044871	3.67562	0.0720076
95.9	29.56	27.504309	1.59624	0.058036
1049.86	198.92	185.08651	14.919	0.0806056
967.1	71.17	66.220625	5.76477	0.087054
51.04	83.68	77.860642	6.19232	0.0795308
4728.6	423.1	393.67636	27.9246	0.0709329
606.11	138.63	128.98925	9.28821	0.0720076
241.51	22.61	21.037633	1.98968	0.0945772
1235	195.07	181.50425	8.97322	0.0494381
227.14	186.18	173.23248	12.1017	0.0698581
162.81	68.43	63.671173	4.58481	0.0720076
112.51	242.91	226.01731	18.94698	0.0838298
192.85	29.72	27.653182	0.62412	0.0225696

635.17	54.36	50.579643	1.30464	0.0257938
2384.1	577.16	537.02256	36.93824	0.0687834
44.43	43.8	40.754017	0.5256	0.0128969
175.5	919.27	855.34121	17.46613	0.0204201
1038.6	99.21	92.310639	8.63127	0.0935024
218.07	147.81	137.53085	10.93794	0.0795308
950.75	159.07	148.0078	12.08932	0.0816803
163.1	99.02	92.133852	6.13924	0.0666339
62.91	59.34	55.213318	3.32304	0.0601855
1468.65	135.67	126.2351	10.17525	0.0806056
173.56	251.73	234.22394	21.14532	0.0902782
792.24	547.34	509.27633	24.08296	0.0472886
56.43	54.21	50.440074	1.24683	0.024719
69.44	33.13	30.82604	0.62947	0.0204201
457.97	483.42	449.80152	31.4223	0.0698581
2031.5	442.74	411.95053	5.31288	0.0128969
487.02	139.88	130.15233	8.67256	0.0666339
242.53	112.49	104.66711	1.68735	0.0161211
130.01	187.69	174.63747	12.57523	0.0720076
820.25	97.12	90.365984	7.57536	0.0838298
57.55	189.86	176.65657	3.98706	0.0225696
198.73	121.65	113.19009	2.9196	0.0257938
38.08	31.35	29.169827	2.03775	0.0698581
35.06	44.07	41.00524	3.26118	0.0795308
86.5	86.33	80.326353	6.64741	0.082755

99.41	96.5	89.789101	6.2725	0.0698581
60.73	96.4	89.696055	7.9048	0.0881287
25.1	20.76	19.316287	1.57776	0.0816803
23.77	20.35	18.9348	0.26455	0.0139716
24.74	21.08	19.614034	0.37944	0.0193453
23.83	20.18	18.776622	0.44396	0.0236443
21.53	20.57	19.1395	0.88451	0.0462138
1931.86	101.44	94.385558	3.95616	0.0419149
1313.38	267.84	249.2136	7.49952	0.0300927
1098.84	105.05	97.744508	7.03835	0.0720076
854.42	143.02	133.07396	8.00912	0.0601855
24.47	10	9.30457	0.75	0.0806056
24.79	10	9.30457	0.84	0.0902782
28.75	10	9.30457	0.44	0.0472886
30.12	10	9.30457	0.23	0.024719
27.66	19.84	18.460267	1.46816	0.0795308
29.91	10	9.30457	0.76	0.0816803
25.93	10	9.30457	0.62	0.0666339
24.58	10	9.30457	0.71	0.0763066
26.2	10	9.30457	0.27	0.029018
26.31	10	9.30457	0.49	0.0526623

Ben[a]P filter (µg/ml)	Ben[a]P tube (µg/ml)	Ben[a]P tube section A (µg/ml)	Ben[a]P tube section B (µg/ml)	Percentage (section B /section A)
221.93	76.74	71.98212	4.75788	0.0660981
225.78	10	9.57	0.43	0.0449321
98.72	10	9.33	0.67	0.0718114
439.68	10	9.46	0.54	0.0570825
170.61	10	9.25	0.75	0.0810811
189.79	10	9.19	0.81	0.0881393
150.01	10	9.26	0.74	0.0799136
703.49	66.23	61.85882	4.37118	0.0706638
717.33	10	9.33	0.67	0.0718114
1357.28	10	9.12	0.88	0.0964912
191.61	10	9.54	0.46	0.048218
105.71	10	9.35	0.65	0.0695187
1026.16	10	9.26	0.74	0.0799136
960.82	10	9.23	0.77	0.0834236
89.83	10	9.35	0.65	0.0695187
3941.6	10	9.18	0.82	0.0893246
757.11	92.61	85.57164	7.03836	0.0822511
198.44	10	9.87	0.13	0.0131712
1073	10	9.82	0.18	0.0183299
371.2	10	9.78	0.22	0.0224949
146.02	59.63	57.06591	2.56409	0.0449321
62.94	10	9.61	0.39	0.0405827
254.32	10	9.72	0.28	0.0288066

502.21	48.74	45.47442	3.26558	0.0718114
2584	49.25	46.492	2.758	0.059322
55.81	10	9.25	0.75	0.0810811
93.46	542.55	496.9758	45.5742	0.0917031
844.95	10	9.56	0.44	0.0460251
129.17	54.29	53.04133	1.24867	0.0235415
664.82	67.08	65.80548	1.27452	0.019368
118.63	53.26	49.7981	3.4619	0.0695187
63.12	52.19	51.56372	0.62628	0.0121457
1183.65	65.58	61.51404	4.06596	0.0660981
233.97	47.19	46.48215	0.70785	0.0152284
765.6	377.79	352.47807	25.31193	0.0718114
93.51	52.49	48.39578	4.09422	0.0845987
64.82	47.52	46.52208	0.99792	0.0214505
342.65	76.38	74.54688	1.83312	0.0245902
2096.55	10	9.36	0.64	0.0683761
667.39	95.97	94.81836	1.15164	0.0121457
279.63	56.43	55.35783	1.07217	0.019368
77.22	70.92	65.88468	5.03532	0.0764263
155.54	10	9.73	0.27	0.0277492
47.54	57.32	54.51132	2.80868	0.0515247
446.51	10	9.68	0.32	0.0330579
52.46	47.75	46.1265	1.6235	0.0351967
49.95	49.7	46.8174	2.8826	0.0615711
105.89	51.5	48.204	3.296	0.0683761

60.06	10	9.16	0.84	0.0917031
76.94	10	9.76	0.24	0.0245902
10	10	9.91	0.09	0.0090817
10	10	9.22	0.78	0.0845987
10	10	9.33	0.67	0.0718114
10	10	9.86	0.14	0.0141988
10	48.59	45.28588	3.30412	0.0729614
1606.96	10	9.55	0.45	0.0471204
1036.9	10	9.62	0.38	0.039501
1161.28	10	9.24	0.76	0.0822511
877.1	10	9.15	0.85	0.0928962
10	10	9.61	0.39	0.0405827
47.25	10	9.13	0.87	0.0952903
48.63	48.03	44.37972	3.65028	0.0822511
48.92	10	9.46	0.54	0.0570825
48.09	10	9.26	0.74	0.0799136
48.61	10	9.38	0.62	0.0660981
47.54	10	9.57	0.43	0.0449321
46.92	10	9.33	0.67	0.0718114
47.51	10	9.46	0.54	0.0570825
47.46	10	9.25	0.75	0.0810811

Appendix. B: OAR 437, DIVISION 2 GENERAL OCCUPATIONAL SAFETY AND HEALTH RULES SUBDIVISION Z – TOXIC AND HAZARDOUS SUBSTANCES

1910.1029(a)

Scope and application. This section applies to the control of employee exposure to coke oven emissions, except that this section shall not apply to working conditions with regard to which other Federal agencies exercise statutory authority to prescribe or enforce standards affecting occupational safety and health.

1910.1029(b)

Definitions. For the purpose of this section:

"Authorized person" means any person specifically authorized by the employer whose duties require the person to enter a regulated area, or any person entering such an area as a designated representative of employees for the purpose of exercising the opportunity to observe monitoring and measuring procedures under paragraph (n) of this section.

"Beehive oven" means a coke oven in which the products of carbonization other than coke are not recovered, but are released into the ambient air.

"Coke oven" means a retort in which coke is produced by the destructive distillation or carbonization of coal.

"Coke oven battery" means a structure containing a number of slot-type coke ovens.

"Coke oven emissions" means the benzene-soluble fraction of total particulate matter present during the destructive distillation or carbonization of coal for the production of coke.

"Director" means the Director, National Institute for Occupational Safety and Health, U.S. Department of Health, Education, and Welfare, or his or her designee.

"Emergency" means any occurrence such as, but not limited to, equipment failure which is likely to, or does, result in any massive release of coke oven emissions.

"Existing coke oven battery" means a battery in operation or under construction on January 20, 1977, and which is not a rehabilitated coke oven battery.

"Rehabilitated coke oven battery" means a battery which is rebuilt, overhauled, renovated, or restored such as from the pad up, after January 20, 1977.

"Secretary" means the Secretary of Labor, U.S. Department of Labor, or his or her designee.

"Stage charging" means a procedure by which a predetermined volume of coal in each larry car hopper is introduced into an oven such that no more than two hoppers are discharging simultaneously.

"Sequential charging" means a procedure, usually automatically timed, by which a predetermined volume of coal in each larry car hopper is introduced into an oven such that no more than two hoppers commence or finish discharging simultaneously although, at some point, all hoppers are discharging simultaneously.

"Pipeline charging" means any apparatus used to introduce coal into an oven which uses a pipe or duct permanently mounted onto an oven and through which coal is charged.

"Green plush" means coke which when removed from the oven results in emissions due to the presence of unvolatilized coal.

1910.1029(c)

Permissible exposure limit. The employer shall assure that no employee in the regulated area is exposed to coke oven emissions at concentrations greater than 150 micrograms per cubic meter of air (150 ug/m(3)), averaged over any 8-hour period.

1910.1029(d)

Regulated areas.

1910.1029(d)(1)

The employer shall establish regulated areas and shall limit access to them to authorized persons.

1910.1029(d)(2)

The employer shall establish the following as regulated areas:

1910.1029(d)(2)(i)

The coke oven battery including topside and its machinery, pushside and its machinery, coke side and its machinery, and the battery ends; the wharf; and the screening station;

1910.1029(d)(2)(ii)

The beehive oven and its machinery.

1910.1029(e)

Exposure monitoring and measurement.

1910.1029(e)(1)

Monitoring program.

1910.1029(e)(1)(i)

Each employer who has a place of employment where coke oven emissions are present shall monitor employees employed in the regulated area to measure their exposure to coke oven emissions.

1910.1029(e)(1)(ii)

The employer shall obtain measurements which are representative of each employee's exposure to coke oven emissions over an eight-hour period. All measurements shall determine exposure without regard to the use of respiratory protection.

1910.1029(e)(1)(iii)

The employer shall collect fullshift (for at least seven continuous hours) personal samples, including at least one sample during each shift for each battery and each job classification within the regulated areas including at least the following job classifications:

1910.1029(e)(1)(iii)(a)

Lidman;

1910.1029(e)(1)(iii)(b)

Tar chaser;

1910.1029(e)(1)(iii)(c)

Larry car operator;

1910.1029(e)(1)(iii)(d)

Luterman;

1910.1029(e)(1)(iii)(e)

Machine operator, coke side;

1910.1029(e)(1)(iii)(f)

Benchman, coke side;

1910.1029(e)(1)(iii)(g)

Benchman, pusher side;

1910.1029(e)(1)(iii)(h)

Heater;

1910.1029(e)(1)(iii)(i)

Quenching car operator;

1910.1029(e)(1)(iii)(j)

Pusher machine operator;

1910.1029(e)(1)(iii)(k)

Screening station operator;

1910.1029(e)(1)(iii)(l)

Wharfman;

1910.1029(e)(1)(iii)(m)

Oven patcher;

1910.1029(e)(1)(iii)(n)

Oven repairman;

1910.1029(e)(1)(iii)(o)

Spellman; and

1910.1029(e)(1)(iii)(p)

Maintenance personnel.

1910.1029(e)(1)(iv)

The employer shall repeat the monitoring and measurements required by this paragraph (e)(1) at least every three months.

1910.1029(e)(2)

Redetermination. Whenever there has been a production, process, or control change which may result in new or additional exposure to coke oven emissions, or whenever the employer has any other reason to suspect an increase in employee exposure, the employer shall repeat the monitoring and measurements required by paragraph (e)(1) of this section for those employees affected by such change or increase.

1910.1029(e)(3)

Employee notification.

1910.1029(e)(3)(i)

The employer must, within 15 working days after the receipt of the results of any monitoring performed under this section, notify each affected employee of these results either individually in writing or by posting the results in an appropriate location that is accessible to employees.

1910.1029(e)(3)(ii)

Whenever such results indicate that the representative employee exposure exceeds the permissible exposure limit, the employer shall, in such notification, inform each employee of that fact and of the corrective action being taken to reduce exposure to or below the permissible exposure limit.

1910.1029(e)(4)

Accuracy of measurement. The employer shall use a method of monitoring and measurement which has an accuracy (with a confidence level of 95%) of not less than plus or minus 35% for concentrations of coke oven emissions greater than or equal to 150 ug/m(3).

1910.1029(f)

Methods of compliance. The employer shall control employee exposure to coke oven emissions by the use of engineering controls, work practices and respiratory protection as follows:

1910.1029(f)(1)

Priority of compliance methods.

1910.1029(f)(1)(i)

Existing coke oven batteries.

1910.1029(f)(1)(i)(a)

The employer shall institute the engineering and work practice controls listed in paragraphs (f)(2), (f)(3) and (f)(4) of this section in existing coke oven batteries at the earliest possible time, but not later than January 20, 1980, except to the extent that the employer can establish that such controls are not feasible. In determining the earliest possible time for institution of engineering and work practice controls, the requirement, effective August 27, 1971, to implement feasible administrative or engineering controls to reduce exposures to coal tar pitch volatiles, shall be considered. Wherever the engineering and work practice controls which can be instituted are not sufficient to reduce employee exposures to or below the permissible exposure limit, the employer shall nonetheless use them to reduce exposures to the lowest level achievable by these controls and shall supplement them by the use of respiratory protection which complies with the requirements of paragraph (g) of this section.

1910.1029(f)(1)(i)(b)

The engineering and work practice controls required under paragraphs (f)(2), (f)(3) and (f)(4) of this section are minimum requirements generally applicable to all existing coke oven batteries. If, after implementing all controls required by paragraphs (f)(2), (f)(3) and (f)(4) of this section, or after January 20, 1980, whichever is sooner, employee exposures still exceed the permissible exposure limit, employers shall implement any other engineering and work practice controls necessary to reduce exposure to or below the permissible exposure limit except to the extent that the employer can establish that such controls are not feasible. Whenever the engineering and work practice controls which can be instituted are not sufficient to reduce employee exposures to or below the permissible exposure limit, the employer shall nonetheless use them to reduce exposures to the lowest level achievable by these controls and shall supplement them by the use of respiratory protection which complies with the requirements of paragraph (g) of this section.

1910.1029(f)(1)(ii)

New or rehabilitated coke oven batteries.

1910.1029(f)(1)(ii)(a)

The employer shall institute the best available engineering and work practice controls on all new or rehabilitated coke oven batteries to reduce and maintain employee exposures at or below the permissible exposure limit, except to the extent that the employer can establish that such controls are not feasible. Wherever the engineering and work practice controls which can be instituted are not sufficient to reduce employee exposures to or below the permissible exposure limit, the employer shall nonetheless use them to reduce exposures to the lowest level achievable by these controls and shall supplement them by the use of respiratory protection which complies with the requirements of paragraph (g) of this section.

1910.1029(f)(1)(ii)(b)

If, after implementing all the engineering and work practice controls required by paragraph (f)(1)(ii)(a) of this section, employee exposures still exceed the permissible exposure limit, the employer shall implement any other engineering and work practice controls necessary to reduce exposure to or below the permissible exposure limit except to the extent that the employer can establish that such controls are not feasible. Wherever the engineering and work practice controls which can be instituted are not sufficient to reduce employee exposures to or below the permissible exposure limit, the employer shall nonetheless use them to reduce exposures to the lowest level achievable by these controls and shall supplement them by the use of respiratory protection which complies with the requirements of paragraph (g) of this section.

1910.1029(f)(1)(iii)

Beehive ovens.

1910.1029(f)(1)(iii)(a)

The employer shall institute engineering and work practice controls on all beehive ovens at the earliest possible time to reduce and maintain employee exposures at or below the permissible exposure limit, except to the extent that the employer can establish that such controls are not feasible. In determining the earliest possible time for institution of engineering and work practice controls, the requirement, effective August 27, 1971, to implement feasible administrative or engineering controls to reduce exposures to coal tar pitch volatiles, shall be considered. Wherever the engineering and work practice controls which can be instituted are not sufficient to reduce employee exposures to or below the permissible exposure limit, the employer shall nonetheless use them to reduce exposures to the lowest level achievable by these controls and shall supplement them by the use of respiratory protection which complies with the requirements of paragraph (g) of this section.

1910.1029(f)(1)(iii)(b)

If, after implementing all engineering and work practice controls required by paragraph (f)(1)(iii)(a) of this section, employee exposures still exceed the permissible exposure limit, the employer shall implement any other engineering and work practice controls necessary to reduce exposures to or below the permissible exposure limit except to the extent that the employer can establish that such controls are not feasible. Whenever the engineering and work practice controls which can be instituted are not sufficient to reduce employee exposures to or below the permissible exposure limit, the employer shall nonetheless use them to reduce exposures to the lowest level achievable by these controls and shall supplement them by the use of respiratory protection which complies with the requirements of paragraph (g) of this section.

1910.1029(f)(2)

Engineering controls.

1910.1029(f)(2)(i)

Charging. The employer shall equip and operate existing coke oven batteries with all of the following engineering controls to control coke oven emissions during charging operations:

1910.1029(f)(2)(i)(a)

One of the following methods of charging:

1910.1029(f)(2)(i)(a)(1)

Stage charging as described in paragraph (f)(3)(i)(b) of this section; or

1910.1029(f)(2)(i)(a)(2)

Sequential charging as described in paragraph (f)(3)(i)(b) of this section except that paragraph (f)(3)(i)(b)(3)(iv) of this section does not apply to sequential charging; or

1910.1029(f)(2)(i)(a)(3)

Pipeline charging or other forms of enclosed charging in accordance with paragraph (f)(2)(i) of this section, except that paragraphs (f)(2)(i)(b), (d), (e), (f) and (h) of this section do not apply;

1910.1029(f)(2)(i)(b)

Drafting from two or more points in the oven being charged, through the use of double collector mains, or a fixed or movable jumper pipe system to another oven, to effectively remove the gases from the oven to the collector mains;

1910.1029(f)(2)(i)(c)

Aspiration systems designed and operated to provide sufficient negative pressure and flow volume to effectively move the gases evolved during charging into the collector mains, including sufficient steam pressure, and steam jets of sufficient diameter;

1910.1029(f)(2)(i)(d)

Mechanical volumetric controls on each larry car hopper to provide the proper amount of coal to be charged through each charging hole so that the tunnel head will be sufficient to permit the gases to move from the oven into the collector mains;

1910.1029(f)(2)(i)(e)

Devices to facilitate the rapid and continuous flow of coal into the oven being charged, such as stainless steel liners, coal vibrators or pneumatic shells;

1910.1029(f)(2)(i)(f)

Individually operated larry car drop sleeves and slide gates designed and maintained so that the gases are effectively removed from the oven into the collector mains;

1910.1029(f)(2)(i)(g)

Mechanized gooseneck and standpipe cleaners;

1910.1029(f)(2)(i)(h)

Air seals on the pusher machine leveler bars to control air infiltration during charging; and

1910.1029(f)(2)(i)(i)

Roof carbon cutters or a compressed air system or both on the pusher machine rams to remove roof carbon.

1910.1029(f)(2)(ii)

Coking. The employer shall equip and operate existing coke oven batteries with all of the following engineering controls to control coke oven emissions during coking operations;

1910.1029(f)(2)(ii)(a)

A pressure control system on each battery to obtain uniform collector main pressure;

1910.1029(f)(2)(ii)(b)

Ready access to door repair facilities capable of prompt and efficient repair of doors, door sealing edges and all door parts;

1910.1029(f)(2)(ii)(c)

An adequate number of spare doors available for replacement purposes;

1910.1029(f)(2)(ii)(d)

Chuck door gaskets to control chuck door emissions until such door is repaired, or replaced; and

1910.1029(f)(2)(ii)(e)

Heat shields on door machines.

1910.1029(f)(3)

Work practice controls.

1910.1029(f)(3)(i)

Charging. The employer shall operate existing coke oven batteries with all of the following work practices to control coke oven emissions during the charging operation:

1910.1029(f)(3)(i)(a)

Establishment and implementation of a detailed, written inspection and cleaning procedure for each battery consisting of at least the following elements:

1910.1029(f)(3)(i)(a)(1)

Prompt and effective repair or replacement of all engineering controls;

1910.1029(f)(3)(i)(a)(2)

Inspection and cleaning of goosenecks and standpipes prior to each charge to a specified minimum diameter sufficient to effectively move the evolved gases from the oven to the collector mains;

1910.1029(f)(3)(i)(a)(3)

Inspection for roof carbon build-up prior to each charge and removal of roof carbon as necessary to provide an adequate gas channel so that the gases are effectively moved from the oven into the collector mains;

1910.1029(f)(3)(i)(a)(4)

Inspection of the steam aspiration system prior to each charge so that sufficient pressure and volume is maintained to effectively move the gases from the oven to the collector mains;

1910.1029(f)(3)(i)(a)(5)

Inspection of steam nozzles and liquor sprays prior to each charge and cleaning as necessary so that the steam nozzles and liquor sprays are clean;

1910.1029(f)(3)(i)(a)(6)

Inspection of standpipe caps prior to each charge and cleaning and luting or both as necessary so that the gases are effectively moved from the oven to the collector mains; and

1910.1029(f)(3)(i)(a)(7)

Inspection of charging holes and lids for cracks, warpage and other defects prior to each charge and removal of carbon to prevent emissions, and application of luting material to standpipe and charging hole lids where necessary to obtain a proper seal.

1910.1029(f)(3)(i)(b)

Establishment and implementation of a detailed written charging procedure, designed and operated to eliminate emissions during charging for each battery, consisting of at least the following elements:

1910.1029(f)(3)(i)(b)(1)

Larry car hoppers filled with coal to a predetermined level in accordance with the mechanical volumetric controls required under paragraph (f)(2)(i)(d) of this section so as to maintain a sufficient gas passage in the oven to be charged;

1910.1029(f)(3)(i)(b)(2)

The larry car aligned over the oven to be charged, so that the drop sleeves fit tightly over the charging holes; and

1910.1029(f)(3)(i)(b)(3)

The oven charged in accordance with the following sequence of requirements:

[i] The aspiration system turned on;

[ii] Coal charged through the outermost hoppers, either individually or together depending on the capacity of the aspiration system to collect the gases involved;

[iii] The charging holes used under paragraph (f)(3)(i)(b)(3)(ii) of this section relidded or otherwise sealed off to prevent leakage of coke oven emissions;

[iv] If four hoppers are used, the third hopper discharged and relidded or otherwise sealed off to prevent leakage of coke oven emissions;

[v] The final hopper discharged until the gas channel at the top of the oven is blocked and then the chuck door opened and the coal leveled;

[vi] When the coal from the final hopper is discharged and the leveling operation complete, the charging hole relidded or otherwise sealed off to prevent leakage of coke oven emissions; and

[vii] The aspiration system turned off only after the charging holes have been closed.

1910.1029(f)(3)(i)(c)

Establishment and implementation of a detailed written charging procedure, designed and operated to eliminate emissions during charging of each pipeline or enclosed charged battery.

1910.1029(f)(3)(ii)

Coking. The employer shall operate existing coke oven batteries pursuant to a detailed written procedure established and implemented for the control of coke oven emissions during coking, consisting of at least the following elements:

1910.1029(f)(3)(ii)(a)

Checking oven back pressure controls to maintain uniform pressure conditions in the collecting main;

1910.1029(f)(3)(ii)(b)

Repair, replacement and adjustment of oven doors and chuck doors and replacement of door jambs so as to provide a continuous metal-to-metal fit;

1910.1029(f)(3)(ii)(c)

Cleaning of oven doors, chuck doors and door jambs each coking cycle so as to provide an effective seal;

1910.1029(f)(3)(ii)(d)

An inspection system and corrective action program to control door emissions to the maximum extent possible; and

1910.1029(f)(3)(ii)(e)

Luting of doors that are sealed by luting each coking cycle and reluting, replacing or adjusting as necessary to control leakage.

1910.1029(f)(3)(iii)

Pushing. The employer shall operate existing coke oven batteries with the following work practices to control coke oven emissions during pushing operations:

1910.1029(f)(3)(iii)(a)

Coke and coal spillage quenched as soon as practicable and not shoveled into a heated oven; and

1910.1029(f)(3)(iii)(b)

A detailed written procedure for each battery established and implemented for the control of emissions during pushing consisting of the following elements:

1910.1029(f)(3)(iii)(b)(1)

Dampering off the ovens and removal of charging hole lids to effectively control coke oven emissions during the push;

1910.1029(f)(3)(iii)(b)(2)

Heating of the coal charge uniformly for a sufficient period so as to obtain proper coking including preventing green pushes;

1910.1029(f)(3)(iii)(b)(3)

Prevention of green pushes to the maximum extent possible;

1910.1029(f)(3)(iii)(b)(4)

Inspection, adjustment and correction of heating flue temperatures and defective flues at least weekly and after any green push, so as to prevent green pushes;

1910.1029(f)(3)(iii)(b)(5)

Cleaning of heating flues and related equipment to prevent green pushes, at least weekly and after any green push.

1910.1029(f)(3)(iv)

Maintenance and repair. The employer shall operate existing coke oven batteries pursuant to a detailed written procedure of maintenance and repair established and implemented for the effective control of coke oven emissions consisting of the following elements:

1910.1029(f)(3)(iv)(a)

Regular inspection of all controls, including goosenecks, standpipes, standpipe caps, charging hold lids and castings, jumper pipes and air seals for cracks, misalignment or other defects and prompt implementation of the necessary repairs as soon as possible;

1910.1029(f)(3)(iv)(b)

Maintaining the regulated area in a neat, orderly condition free of coal and coke spillage and debris;

1910.1029(f)(3)(iv)(c)

Regular inspection of the damper system, aspiration system and collector main for cracks or leakage, and prompt implementation of the necessary repairs;

1910.1029(f)(3)(iv)(d)

Regular inspection of the heating system and prompt implementation of the necessary repairs;

1910.1029(f)(3)(iv)(e)

Prevention of miscellaneous fugitive topside emissions;

1910.1029(f)(3)(iv)(f)

Regular inspection and patching of oven brickwork;

1910.1029(f)(3)(iv)(g)

Maintenance of battery equipment and controls in good working order;

1910.1029(f)(3)(iv)(h)

Maintenance and repair of coke oven doors, chuck doors, door jambs and seals; and

1910.1029(f)(3)(iv)(i)

Repairs instituted and completed as soon as possible, including temporary repair measures instituted and completed where necessary, including but not limited to:

1910.1029(f)(3)(iv)(i)(1)

Prevention of miscellaneous fugitive topside emissions; and

1910.1029(f)(3)(iv)(i)(2)

Chuck door gaskets, which shall be installed prior to the start of the next coking cycle.

1910.1029(f)(4)

Filtered air.

1910.1029(f)(4)(i)

The employer shall provided positive-pressure, temperature controlled filtered air for larry car, pusher machine, door machine, and quench car cabs.

1910.1029(f)(4)(ii)

The employer shall provide standby pulpits on the battery topside, at the wharf, and at the screening station, equipped with positive-pressure, temperature controlled filtered air.

1910.1029(f)(5)

Emergencies. Whenever an emergency occurs, the next coking cycle may not begin until the cause of the emergency is determined and corrected, unless the employer can establish that it is necessary to initiate the next coking cycle in order to determine the cause of the emergency.

1910.1029(f)(6)

Compliance program.

1910.1029(f)(6)(i)

Each employer shall establish and implement a written program to reduce exposures solely by means of the engineering and work practice controls required in paragraph (f) of this section.

1910.1029(f)(6)(ii)

The written program shall include at least the following:

1910.1029(f)(6)(ii)(a)

A description of each coke oven operation by battery, including work force and operating crew, coking time, operating procedures and maintenance practices;

1910.1029(f)(6)(ii)(b)

Engineering plans and other studies used to determine the controls for the coke battery;

1910.1029(f)(6)(ii)(c)

A report of the technology considered in meeting the permissible exposure limit;

1910.1029(f)(6)(ii)(d)

Monitoring data obtained in accordance with paragraph (e) of this section;

1910.1029(f)(6)(ii)(e)

A detailed schedule for the implementation of the engineering and work practice controls required in paragraph (f) of this section; and

1910.1029(f)(6)(ii)(f)

Other relevant information.

1910.1029(f)(6)(iii)

If, after implementing all controls required by paragraph (f)(2) - (f)(4) of this section, or after January 20, 1980, whichever is sooner, or after completion of a new or rehabilitated battery the permissible exposure limit is still exceeded, the employer shall develop a detailed written program and schedule for the implementation of any additional engineering controls and work practices necessary to reduce exposure to or below the permissible exposure limit.

1910.1029(f)(6)(iv)

Written plans for such programs shall be submitted, upon request, to the Secretary and the Director, and shall be available at the worksite for examination and copying by the Secretary, the Director, and the authorized employee representative. The plans required under paragraph (f)(6) of this section shall be revised and updated at least annually to reflect the current status of the program.

1910.1029(f)(7)

Training in compliance procedures. The employer shall incorporate all written procedures and schedules required under this paragraph (f) in the information and training program required under paragraph (k) of this section and, where appropriate, post in the regulated area.

1910.1029(g)

Respiratory protection.

1910.1029(g)(1)

General. For employees who use respirators required by this section, the employer must provide each employee an appropriate respirator that complies with the requirements of this paragraph. Respirators must be used during:

1910.1029(g)(1)(i)

Periods necessary to install or implement feasible engineering and work-practice controls.

1910.1029(g)(1)(ii)

Work operations, such as maintenance and repair activity, for which engineering and work-practice controls are technologically not feasible.

1910.1029(g)(1)(iii)

Work operations for which feasible engineering and work-practice controls are not yet sufficient to reduce employee exposure to or below the permissible exposure limit.

1910.1029(g)(1)(iv)

Emergencies.

1910.1029(g)(2)

Respirator program. The employer must implement a respiratory protection program in accordance with § 1910.134(b) through (d) (except (d)(1)(iii)), and (f) through (m), which covers each employee required by this section to use a respirator.

1910.1029(g)(3)

Respirator selection. Employers must select, and provide to employees, the appropriate respirators specified in paragraph (d)(3)(i)(A) of 29 CFR 1910.134; however, employers may use a filtering facepiece respirator only when it functions as a filter respirator for coke oven emissions particulates.

1910.1029(h)

Protective clothing and equipment.

1910.1029(h)(1)

Provision and use. The employer shall provide and assure the use of appropriate protective clothing and equipment, such as but not limited to:

1910.1029(h)(1)(i)

Flame resistant jacket and pants;

1910.1029(h)(1)(ii)

Flame resistant gloves;

1910.1029(h)(1)(iii)

Face shields or vented goggles which comply with 1910.133(a)(2) of this part;

1910.1029(h)(1)(iv)

Footwear providing insulation from hot surfaces for footwear;

1910.1029(h)(1)(v)

Safety shoes which comply with 1910.136 of this part; and

1910.1029(h)(1)(vi)

Protective helmets which comply with 1910.135 of this part.

1910.1029(h)(2)

Cleaning and replacement.

1910.1029(h)(2)(i)

The employer shall provide the protective clothing required by paragraphs (h)(1)(i) and (ii) of this section in a clean and dry condition at least weekly.

1910.1029(h)(2)(ii)

The employer shall clean, launder, or dispose of protective clothing required by paragraphs (h)(1)(i) and (ii) of this section.

1910.1029(h)(2)(iii)

The employer shall repair or replace the protective clothing and equipment as needed to maintain their effectiveness.

1910.1029(h)(2)(iv)

The employer shall assure that all protective clothing is removed at the completion of a work shift only in change rooms prescribed in paragraph (i)(1) of this section.

1910.1029(h)(2)(v)

The employer shall assure that contaminated protective clothing which is to be cleaned, laundered, or disposed of, is placed in a closable container in the change room.

1910.1029(h)(2)(vi)

The employer shall inform any person who cleans or launders protective clothing required by this section, of the potentially harmful effects of exposure to coke oven emissions.

1910.1029(i)

Hygiene facilities and practices.

1910.1029(i)(1)

Change rooms. The employer shall provide clean change rooms equipped with storage facilities for street clothes and separate storage facilities for protective clothing and equipment whenever employees are required to wear protective clothing and equipment in accordance with paragraph (h)(1) of this section.

1910.1029(i)(2)

Showers.

1910.1029(i)(2)(i)

The employer shall assure that employees working in the regulated area shower at the end of the work shift.

1910.1029(i)(2)(ii)

The employer shall provide shower facilities in accordance with 1910.141(d)(3) of this part.

1910.1029(i)(3)

Lunchrooms. The employer shall provide lunchroom facilities which have a temperature controlled, positive pressure, filtered air supply, and which are readily accessible to employees working in the regulated area.

1910.1029(i)(4)

Lavatories.

1910.1029(i)(4)(i)

The employer shall assure that employees working in the regulated area wash their hands and face prior to eating.

1910.1029(i)(4)(ii)

The employer shall provide lavatory facilities in accordance with 1910.141(d)(1) and (2) of this part.

1910.1029(i)(5)

Prohibition of activities in the regulated area.

1910.1029(i)(5)(i)

The employer shall assure that in the regulated area, food or beverages are not present or consumed, smoking products are not present or used, and cosmetics are not applied, except that these activities may be conducted in the lunchrooms, change rooms and showers required under paragraphs (i)(1) - (i)(3) of this section.

1910.1029(i)(5)(ii)

Drinking water may be consumed in the regulated area.

1910.1029(j)

Medical surveillance.

1910.1029(j)(1)

General requirements.

1910.1029(j)(1)(i)

Each employer shall institute a medical surveillance program for all employees who are employed in a regulated area at least 30 days per year.

1910.1029(j)(1)(ii)

This program shall provide each employee covered under paragraph (j)(1)(i) of this section with an opportunity for medical examinations in accordance with this paragraph (j).

1910.1029(j)(1)(iii)

The employer shall inform any employee who refuses any required medical examination of the possible health consequences of such refusal and shall obtain a signed statement from the employee indicating that the employee understands the risk involved in the refusal to be examined.

1910.1029(j)(1)(iv)

The employer shall assure that all medical examinations and procedures are performed by or under the supervision of a licensed physician, and are provided without cost to the employee.

1910.1029(j)(2)

Initial examinations. At the time of initial assignment to a regulated area or upon the institution of the medical surveillance program, the employer shall provide a medical examination for employees covered under paragraph (j)(1)(i) of this section including at least the following elements:

1910.1029(j)(2)(i)

A work history and medical history which shall include smoking history and the presence and degree of respiratory symptoms, such as breathlessness, cough, sputum production, and wheezing;

1910.1029(j)(2)(ii)

A standard posterior-anterior chest x-ray;

1910.1029(j)(2)(iii)

Pulmonary function tests including forced vital capacity (FVC) and forced expiratory volume at one second (FEV 1.0) with recording of type of equipment used;

1910.1029(j)(2)(iv)

Weight;

1910.1029(j)(2)(v)

A skin examination;

1910.1029(j)(2)(vi)

Urinalysis for sugar, albumin, and hematuria; and

1910.1029(j)(2)(vii)

A urinary cytology examination.

1910.1029(j)(2)(viii)

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1910.1029(j)(3)

Periodic examinations.

1910.1029(j)(3)(i)

The employer shall provide the examinations specified in paragraphs (j)(2)(i)-(vi) of this section at least annually for employees covered under paragraph (j)(1)(i) of this section.

1910.1029(j)(3)(ii)

The employer must provide the examinations specified in paragraphs (j)(2)(i) through (j)(2)(vii) of this section at least annually for employees 45 years of age or older or with five (5) or more years employment in the regulated area.

1910.1029(j)(3)(iii)

Whenever an employee who is 45 years of age or older or with five (5) or more years employment in a regulated area transfers or is transferred from employment in a regulated area, the employer must continue to provide the examinations specified in paragraphs (j)(2)(i) through (j)(2)(vii) of this section at least annually as long as that employee is employed by the same employer or a successor employer.

1910.1029(j)(3)(iv)

Whenever an employee has not taken the examinations specified in paragraphs (j)(3)(i)-(iii) of this section with the six (6) months preceding the termination of employment the employer shall provide such examinations to the employee upon termination of employment.

1910.1029(j)(4)

Information provided to the physician. The employer shall provide the following information to the examining physician:

1910.1029(j)(4)(i)

A copy of this regulation and its Appendixes;

1910.1029(j)(4)(ii)

A description of the affected employee's duties as they relate to the employee's exposure;

1910.1029(j)(4)(iii)

The employee's exposure level or estimated exposure level;

1910.1029(j)(4)(iv)

A description of any personal protective equipment used or to be used; and

1910.1029(j)(4)(v)

Information from previous medical examinations of the affected employee which is not readily available to the examining physician.

1910.1029(j)(5)

Physician's written opinion.

1910.1029(j)(5)(i)

The employer shall obtain a written opinion from the examining physician which shall include:

1910.1029(j)(5)(i)(a)

The results of the medical examinations;

1910.1029(j)(5)(i)(b)

The physician's opinion as to whether the employee has any detected medical conditions which would place the employee at increased risk of material impairment of the employee's health from exposure to coke oven emissions;

1910.1029(j)(5)(i)(c)

Any recommended limitations upon the employee's exposure to coke oven emissions or upon the use of protective clothing or equipment such as respirators; and

1910.1029(j)(5)(i)(d)

A statement that the employee has been informed by the physician of the results of the medical examination and any medical conditions which require further explanation or treatment.

1910.1029(j)(5)(ii)

The employer shall instruct the physician not to reveal in the written opinion specific findings or diagnoses unrelated to occupational exposure.

1910.1029(j)(5)(iii)

The employer shall provide a copy of the written opinion to the affected employee.

1910.1029(k)

Employee information and training.

1910.1029(k)(1)

Training program.

1910.1029(k)(1)(i)

The employer shall train each employee who is employed in a regulated area in accordance with the requirements of this section. The employer shall institute a training program and ensure employee participation in the program.

1910.1029(k)(1)(ii)

The training program shall be provided as of January 27, 1977 for employees who are employed in the regulated area at that time or at the time of initial assignment to a regulated area.

1910.1029(k)(1)(iii)

The training program shall be provided at least annually for all employees who are employed in the regulated area, except that training regarding the occupational safety and health hazards associated with exposure to coke oven emissions and the purpose, proper use, and limitations of respiratory protective devices shall be provided at least quarterly until January 20, 1978.

1910.1029(k)(1)(iv)

The training program shall include informing each employee of:

1910.1029(k)(1)(iv)(a)

The information contained in the substance information sheet for coke oven emissions (Appendix A);

1910.1029(k)(1)(iv)(b)

The purpose, proper use, and limitations of respiratory protective devices required in accordance with paragraph (g) of this section;

1910.1029(k)(1)(iv)(c)

The purpose for and a description of the medical surveillance program required by paragraph (j) of this section including information on the occupational safety and health hazards associated with exposure to coke oven emissions;

1910.1029(k)(1)(iv)(d)

A review of all written procedures and schedules required under paragraph (f) of this section; and

1910.1029(k)(1)(iv)(e)

A review of this standard.

1910.1029(k)(2)

Access to training materials.

1910.1029(k)(2)(i)

The employer shall make a copy of this standard and its appendixes readily available to all employees who are employed in the regulated area.

1910.1029(k)(2)(ii)

The employer shall provide upon request all materials relating to the employee information and training program to the Secretary and the Director.

1910.1029(l)

Precautionary signs and labels.

1910.1029(l)(1)

General.

1910.1029(l)(1)(i)

The employer may use labels or signs required by other statutes, regulations or ordinances in addition to, or in combination with, signs and labels required by this paragraph.

1910.1029(l)(1)(ii)

The employer shall assure that no statement appears on or near any sign required by this paragraph which contradicts or detracts from the effects of the required sign.

1910.1029(l)(1)(iii)

The employer shall assure that signs required by this paragraph are illuminated and cleaned as necessary so that the legend is readily visible.

1910.1029(l)(2)

Signs.

1910.1029(l)(2)(i)

The employer shall post signs in the regulated area bearing the legends:

DANGER

CANCER HAZARD

AUTHORIZED PERSONNEL ONLY

NO SMOKING OR EATING

1910.1029(l)(2)(ii)

In addition, not later than January 20, 1978, the employer shall post signs in the areas where the permissible exposure limit is exceeded bearing the legend:

DANGER

RESPIRATOR REQUIRED

1910.1029(l)(3)

Labels. The employer shall apply precautionary labels to all containers of protective clothing contaminated with coke oven emissions bearing the legend:

CAUTION

CLOTHING CONTAMINATED WITH COKE EMISSIONS

DO NOT REMOVE DUST BY BLOWING OR SHAKING

1910.1029(m)

Recordkeeping.

1910.1029(m)(1)

Exposure measurements. The employer shall establish and maintain an accurate record of all measurements taken to monitor employee exposure to coke oven emissions required in paragraph (e) of this section.

1910.1029(m)(1)(i)

This record shall include:

1910.1029(m)(1)(i)(a)

Name, social security number, and job classification of the employees monitored;

1910.1029(m)(1)(i)(b)

The date(s), number, duration and results of each of the samples taken, including a description of the sampling procedure used to determine representative employee exposure where applicable;

1910.1029(m)(1)(i)(c)

The type of respiratory protective devices worn, if any;

1910.1029(m)(1)(i)(d)

A description of the sampling and analytical methods used and evidence of their accuracy; and

1910.1029(m)(1)(i)(e)

The environmental variables that could affect the measurement of employee exposure.

1910.1029(m)(1)(ii)

The employer shall maintain this record for at lest 40 years or for the duration of employment plus 20 years, whichever is longer.

1910.1029(m)(2)

Medical surveillance. The employer shall establish and maintain an accurate record for each employee subject to medical surveillance as required by paragraph (j) of this section.

1910.1029(m)(2)(i)

The record shall include:

1910.1029(m)(2)(i)(a)

The name, social security number, and description of duties of the employee;

1910.1029(m)(2)(i)(b)

A copy of the physician's written opinion;

1910.1029(m)(2)(i)(c)

The signed statement of any refusal to take a medical examination under paragraph (j)(1)(ii) of this section; and

1910.1029(m)(2)(i)(d)

Any employee medical complaints related to exposure to coke oven emissions.

1910.1029(m)(2)(ii)

The employer shall keep, or assure that the examining physician keeps, the following medical records:

1910.1029(m)(2)(ii)(a)

A copy of the medical examination results including medical and work history required under paragraph (j)(2) of this section;

1910.1029(m)(2)(ii)(b)

A description of the laboratory procedures used and a copy of any standards or guidelines used to interpret the test results;

1910.1029(m)(2)(ii)(c)

The initial x-ray;

1910.1029(m)(2)(ii)(d)

The x-rays for the most recent five (5) years;

1910.1029(m)(2)(ii)(e)

Any x-ray with a demonstrated abnormality and all subsequent x-rays;

1910.1029(m)(2)(ii)(f)

The initial cytologic examination slide and written description;

1910.1029(m)(2)(ii)(g)

The cytologic examination slide and written description for the most recent 10 years; and

1910.1029(m)(2)(ii)(h)

Any cytologic examination slides with demonstrated atypia, if such atypia persists for 3 years, and all subsequent slides and written descriptions.

1910.1029(m)(2)(iii)

The employer shall maintain medical records required under paragraph (m)(2) of this section for at least 40 years, or for the duration of employment plus 20 years, whichever is longer.

1910.1029(m)(3)

Availability.

1910.1029(m)(3)(i)

The employer shall make available upon request all records required to be maintained by paragraph (m) of this section to the Secretary and the Director for examination and copying.

1910.1029(m)(3)(ii)

Employee exposure measurement records and employee medical records required by this paragraph shall be provided upon request to employees, designated representatives, and the Assistant Secretary in accordance with 29 CFR 1910.1020(a)-(e) and (g)-(i).

1910.1029(m)(4)

Transfer of records.

1910.1029(m)(4)(i)

Whenever the employer ceases to do business, the successor employer shall receive and retain all records required to be maintained by paragraph (m) of this section.

1910.1029(m)(4)(ii)

Whenever the employer ceases to do business and there is no successor employer to receive and retain the records for the prescribed period, these records shall be transmitted by registered mail to the Director.

1910.1029(m)(4)(iii)

At the expiration of the retention period for the records required to be maintained under paragraphs (m)(1) and (m)(2) of this section, the employer shall transmit these records by registered mail to the Director or shall continue to retain such records.

1910.1029(m)(4)(iv)

The employer shall also comply with any additional requirements involving transfer of records set forth in 29 CFR 1910.1020(h).

1910.1029(n)

Observation of monitoring.

1910.1029(n)(1)

Employee observation. The employer shall provide affected employees or their representatives an opportunity to observe any measuring or monitoring of employee exposure to coke oven emissions conducted pursuant to paragraph (e) of this section.

1910.1029(n)(2)

Observation procedures.

1910.1029(n)(2)(i)

Whenever observation of the measuring or monitoring of employee exposure to coke oven emissions requires entry into an area where the use of protective clothing or equipment is required, the employer shall provide the observer with and assure the use of such equipment and shall require the observer to comply with all other applicable safety and health procedures.

1910.1029(n)(2)(ii)

Without interfering with the measurement, observers shall be entitled to:

1910.1029(n)(2)(ii)(a)

An Explanation of the measurement procedures;

1910.1029(n)(2)(ii)(b)

Observe all steps related to the measurement of coke oven emissions performed at the place of exposure; and

1910.1029(n)(2)(ii)(c)

Record the results obtained.