ISSN : 2454-4736 (Online)
ISSN : 2454-8723 (Print)
Vol. 1, Issue 1 (Apr. - Jun. 2015)
International Journal of Advanced Research in Mechanical Engineering & Technology (IJARMET)

Impact of Welding Processes on Environment and Health

Pankaj Kumar.J. Mistry
Dept. of Mechanical Engineering, Rungta Engineering College, Raipur, CG, India

Abstract
Environment considerations today tend to control, guide and develop engineering processes affecting both men and environment. The melting of filler metal, base metal and the coating on base metal during welding processes and subsequently the gases formed release minute, solid particles into the air creating a plume and is called welding fume. Compared to other industrial production processes, welding is fairly dangerous. Welding processes involve the potential hazards for inhalation exposures that may lead to acute or chronic respiratory diseases. Risks include asphyxiation due to dangerous inhalants, damage to skin and eye due to ultraviolet light, chemical or electrical fires, and long-term negative effects from fumes.
This article is adapted from recent print and online resources to provide an overview of welding fumes, health effects and the measures to protect welders from welding fumes. This review describes the information currently available on air pollutant effects in welders, as the result of experimental studies. Results from the analysis shows that most of the welders' posses limited knowledge of welding fumes hazard. The aim of this review is to gather the potential toxic effects of welding fumes documented by individual efforts and spread awareness about the environmental and health hazards of welding fumes.

Key Words
Welding Processes, Environmental Hazards, Fumes and gases, Health effects, Ventilation.

I. Introduction

Welding is a process of joining two metal parts together by applying intense heat between them, which causes the parts to intermix after melting. Welding processes are widely used for the manufacture of shipyards, civil engineering structures, mining industry transportation means, petrochemical industry, and metallurgy. The intense heat of the arc or flame vaporizes the base metal and/or electrode coating. This vaporized metal condenses into minute particles called fumes that can be inhaled [1]. All welding processes generate fumes, but most fumes are produced during electric arc welding. The thermal effects can cause agglomeration of the particles into particle chains and clusters that can be deposited in the human respiratory tract [2, 3, 4]. Most of the fume particles are less than 1micron in diameter when produced, but they tend to grow in size with time due to agglomeration [5, 6].

Environment considerations tend to control, guide and develop engineering processes affecting both health and environment. In industrialized countries, around 2 % of the labor force works in the welding field. These workers are exposed to smoke and toxic gas emitted during the welding processes, which may endanger their health [7].

The vulnerability of welding depends on numerous factors: 1) type of welding process, 2) material being welded, 3) electrode material, 4) presence of coatings on the metal, 5) voltage and current used and 6) type of ventilation [8,9].

II. Environmental Hazards of Welding

Most of the small and medium enterprises (SMEs) have poor working conditions contributing to worker's safety and health problem. Most welders who work in construction, factories, mining, manufacturing, metallurgy, railroad, petrochemical, ironworks, shipbuilding or steel industries, suffer from some kind of respiratory illness or pulmonary infection. Toxic gases like nitric oxide, carbon monoxide, ozone and nitrogen dioxide are produced from welding processes. These toxic gases can cause headache, pulmonary edema and drowsiness [8]. Phosphine and phosgene are the other gases which are a health hazard. Ozone, a colorless gas produced during welding, is a powerful irritant which attacks the cell membrane and the mucous membrane. Ordinarily safe gases become too concentrated if welders work in confined space, and cause edema, filling lungs with water.

Nitrous gases (nitrogen oxides) form when the nitrogen and oxygen in the air react with the hot arc and the hot base metal. NO2 is present in workplaces where combustion processes or gas welding is in use [10]. The exposure limit for NO2 for an 8 hour work shift in most European countries is 2 parts per million, and the peak exposure limit for workplaces is 5 parts per million. Concentrations up to these levels occur and are sometimes exceeded [11]. These nitrous gases affect the lungs.

Carbon monoxide forms during MAG welding as a result of the atomization of carbon dioxide in the shielding gas. Carbon monoxide affects the ability of the blood to absorb oxygen. Table-1 shows the type of gas, its source and its effect/symptoms on welders

Table 1: Type of Gas, Source and its Effect/Symptoms on Welders 18]

Type of Gas	Source	Effects / Symptoms
Carbon Monoxide	Formed in welding arc.	Readily absorbed in the bloodstream causing dizziness headache, or muscular weakness. Unconsciousness and death may result due to high concentrations.
Hydrogen Fluoride	Decomposition of electrode coatings.	Irritates the eyes and respiratory tract. Lung, kidney, bone and liver damage can be caused due to overexposure. Chronic exposure results in persistent irritation of the throat, nose and bronchi.

© All Rights Reserved, IJARMET 2015

ISSN : 2454-4736 (Online)
ISSN : 2454-8723 (Print)

Nitrogen Oxide	Formed in the welding arc.	Higher concentrations lead to abnormal fluid in the lung and other serious effects Low concentrations causes eye, nose and throat irritation. Chronic effects include lung problems like emphysema.
Oxygen Deficiency	Welding in confined spaces, displacement of air by shielding gas.	Dizziness, mental perplexity, asphyxiation and death.
Ozone	Formed in the welding arc, especially during Gas Metal, Tungsten Inert and Plasma-Arc, Welding processes.	Very low concentration (1ppm) causes dryness of the eyes and headaches. Acute effects include fluid in the lungs and hemorrhaging. Chronic effects include significant changes in lung function.

III. Health Effects of Welding Fumes

The vaporized metal produced by the heat of the welding process oxidises to produce a fume containing particles of metal oxide such as aluminium, cadmium, chromium, and copper [12]. The health effects of welding fume can vary considerably as they are dependent on the exact composition of metals involved in the weld, composition of the electrode, fluxes and the cleaning agents used. Workers deal with great percentage of health injuries when they are exposed to the toxic gases and fumes [13]. The effects on health may be acute (occurred following short-term inhalation of various gas and smoke) or chronic (long-term effects).The toxic gases and fumes do not affect the workers health in short period of time but long exposure to the toxic gases and fumes tends to cause serious health damage. Each type of fumes and the toxic gases has its own concentration to affect the workers health and give different health effect. The major toxic gases associated with welding are classifies as primary pulmonary and non pulmonary [14].

Table 2 shows the threshold limit value (TLV) for selected metals. TLV is the recommended exposures level to substances in the industrial environment. Workers can tolerate exposure below the TLV day after day at 8 hours per day for a working life without adverse health effects. The TLVs for fumes and dusts are in mg per cubic meter [15].

Welding fume particles are comprised of a large proportion of nano-particles [16].In fact, most of fumes and gases are smaller than one micrometer. At this size, the particles penetrate deep into the respiratory tract (they can reach the narrowest branches of the respiratory organs). Fig.1 shows particle sizes for a number of familiar pollutants [15].

Table: 2 Threshold limit values (TLV) for selected metals [15].

Substance	Threshold Limit Value-8 Hour Time Weighted Average
Aluminum metal and insoluble compounds	1 mg/m³
Antimony and compounds, as Sb	0.5 mg/m³
Arsenic and inorganic arsenic compounds, as As	0.01 mg/m³ (A1)
Beryllium and compounds as Be	0.00005 mg/m³ (A1)
Cadmium	0.01 mg/m³ (A2)
compounds, as Cd	0.002 mg/m³ (A2)
Chromium and inorganic compounds, as Cr	
Metal and Cr III compounds	0.5 mg/m³ (A4)
Water-soluble Cr VI compounds	0.05 mg/m³ (A1)
Insoluble Cr VI compounds	0.01 mg/m³ (A1)
Cobalt and inorganic compounds, as Co	0.02 mg/m³ (A3)
Iron Oxide	5 mg/m³ (A4)
Lead and inorganic lead compounds, as Pb	0.05 mg/m³ (A3)
Manganese and inorganic compounds, as Mn	0.2 mg/m³ *
Nickel, as Ni	
Elemental	1.5 mg/m³ (A5)
Soluble inorganic compounds	0.1 mg/m³ (A4)
Insoluble inorganic compounds	0.2 mg/m³ (A1)
Zinc oxide	2 mg/m³

A1: Confirmed Human Carcinogen
A2: Suspected Human Carcinogen
A3: Confirmed Animal Carcinogen with Unknown Relevance to Humans
A4: Not Classifiable as a Human Carcinogen
A5: Not Suspected as a Human Carcinogen

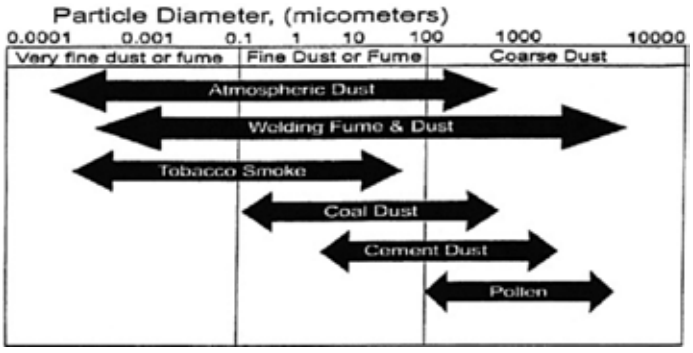

Fig. 1 Particle sizes for different pollutants [15].

Fig. 2 shows the concentration of respirable particulates in breathing zone of welders and non welders. The average concentration of respirable particulates in the breathing zones of welders was four times as high as in the breathing zones of non-welders. Table 3 shows the health effects of fumes and organic vapours produced during welding.

© 2015, IJARMET All Rights Reserved

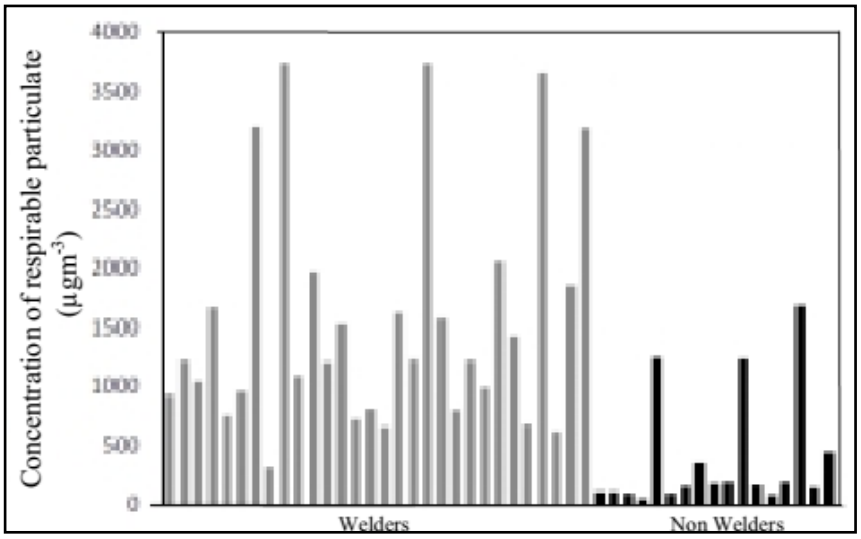

Fig. 2: Concentration of respirable particulates in breathing zone of welders and non welders [17].

Table: 3 Health Effects of Fumes and Organic Vapours Produced During Welding [18].

Fume Type	Source	Effects and Symptoms
Aluminum	Aluminum constituent of some alloys, e.g., copper, brass, inconel, steel, magnesium, zinc, and filler materials.	Respiratory irritant.
Beryllium	Hardening agent found in magnesium, copper, aluminum alloys and electrical contacts.	"Metal Fume Fever." A carcinogen. Other chronic effects include damage to the respiratory tract.
Cadmium Oxides	Stainless steel containing cadmium or plated materials, zinc alloy.	Irritation of respiratory system, chest pain and breathing difficulty ,sore and dry throat,.chronic effects include kidney damage and emphysema. Suspected carcinogen.
Chromium	Welding rods, most stainless-steel and high alloy materials. Also used as plating material.	Increased risk of lung cancer. Some individuals may develop skin irritation. Some forms are carcinogens (hexavalent chromium).
Copper	Alloys like monel, bronze, brass. Also some welding rods.	Acute effects include irritation of the eyes, nose and throat, nausea and "Metal Fume Fever."
Fluorides	Common electrode coating and flux material for both low and high alloy steels.	Acute effect is irritation of the eyes, nose and throat. Long-term exposures may result in bone and joint problems. Chronic effects excess fluid in the lungs.
Iron Oxide	Major contaminant in all iron / steel welding processes.	Siderosis – a benign form of lung disease caused by particles deposited in the lungs. Acute symptoms include irritation of the nose and lungs.
Lead	Solder, brass and bronze alloys, primer/ coating on steels.	Affects nervous system, digestive system, kidneys, and mental capacity. Can cause lead poisoning.
Manganese	Most welding processes, especially high-tensile steels.	"Metal Fume Fever." Chronic effects may affect central nervous system.
Molybdenum	Iron, steel alloys, stainless steel, nickel alloys.	Eye, nose and throat irritation, shortness of breath.
Nickel	Stainless steel, Inconel, Monel, Hastelloy and other high-alloy materials, welding rods and plated steel.	Acute effect is irritation of the eyes, nose and throat. Increased cancer risk has been noted in occupations other than welding. Also associated with dermatitis and lung problems.
Vanadium	Some steel alloys, iron, stainless steel, nickel alloys.	Acute effect is irritation of the eyes, skin and respiratory tract. Chronic effects include bronchitis, retinitis, fluid in the lungs and pneumonia.
Zinc Oxides	Galvanized and painted metal.	"Metal Fume Fever."
Organic Vapours Type	Source	Effects and Symptoms

© All Rights Reserved, IJARMET 2015

ISSN : 2454-4736 (Online)
ISSN : 2454-8723 (Print)

Aldehydes (such as formaldehyde)	Metal coating with binders and pigments. Degreasing solvents.	Irritant to eyes and respiratory tract.
Diisocyanates	Metal with polyurethane paint.	Nose, eye and throat irritation. High possibility of sensitization, producing asthmatic or other allergic symptoms, even at very low exposures.
Phosgene	Metal with residual degreasing solvents. (Phosgene is formed by reaction of the solvent and welding radiation.)	Severe irritant to nose, eyes and respiratory system. Symptoms may be delayed.
Phosphine	Metal coated with rust inhibitors. (Phosphine is formed by reaction of the rust inhibitor with welding radiation.)	Irritant to eyes and respiratory system, can damage kidneys , other organs.

IV. Measures to Protect Welders From Welding Fumes

During indoor welding, proper ventilation systems like roof vents, hoods and high-speed exhaust fans and intake are incorporated into work areas. Modern welding guns can also help to extract fumes from the air. In large work areas, the use of downdraft worktables is recommended so that the fumes are directed down and away from the welder's breathing space. Ceilings more than 16 feet high and routine air monitoring to determine any changes in exposure levels helps to reduce welding fumes and gases in work areas..For outdoor welding operations, welders must avoid standing directly in or near the fume plume and to work upwind to reduce their exposure. Fans may also be used to blow fumes away from welders. Respirators and training must be provided to welders for their well being.

V. Conclusions

Analyzing the obtained data, the following general conclusions can be drawn:

1. Ventilation, respiration and exhaust systems greatly decrease the health hazards.
2. Standing directly in or near the fume plume should be avoided.
3. Respirators and training must be provided to welders for their well being.
4. Welders should be provided with personal protective equipment .
5. Reduce exposure to fumes and gases by adopting stringent controls for safe work practices and work –rest schedules.

References

[1]. Azian Hariri, Preliminary Measurement of Welding Fumes in Automotive Plants, International Journal of Environmental Science and Development, Vol. 3, No. 2, April 2012, pp 146-151

[2]. H. S. Ashby, Welding Fumes in the Workplace: Preventing Potential Health Problems Through Proactive Controls, Professional Safety, pp. 55-60, Apr 2002.

[3]. S. R. Fiore, Reducing Exposure toHexavalent Chromium in Welding Fumes, Welding Journal, August 2006 pp. 38-43,.

[4]. E. Ravert, Controlling Chromium Fumes, Welding Journal, November 2006

[5]. Mansouri et al, Gravimetric and analytical evaluation of welding fume in an automobile part manufacturing factory. J. Res. Health Sci., 8, 2008, pp 1-8.

[6]. Isaxon et al., Characteristics of welding fume aerosol investigated in three Swedish workshops, Journal of Physics: Conference Series, 151(1), 012059. http://dx.doi. org/10.1088/1742-6596/151/1/012059), 2009.

[7]. Gheorghe.A, Research on environmental pollution when using shielded metal arc welding (SMAW), U.P.B. Sci. Bull., Series D, Vol. 72, Iss. 3, 2010, ISSN 1454-2358, pp 73-88.

[8]. Blunt and Balchin, Health and safety in welding and allied processes, Cambridge: Woodhead Publishing Limited., 2000.

[9]. Hewitt, P. J., Strategies for risk assesment and control in welding: challenges for developing countries, Ann. occup. Hyg., 45(4), 2001, pp 295-298.

[10]. World Health Organization. Oxides of nitrogen, Environmental Health Criteria 4. WHO, Geneva, 1977.

[11]. T. Sandström, Respiratory effects of air pollutants: experimental studies in humans, Eur Respir J, 8, 1995, 976–995.

[12]. Antonini J.M, Health effects of welding. Crit Rev Toxicol 2003, 33:61-103

[13]. American Welding Society: Fumes and gases, Safety and Health Fact Sheet no 1.2005 Miami. FL

[14]. A.M Leman, Monitoring of welding work environment in small and medium industries (SMIs) , IJRRAS 5 (1) , October 2010, pp 18-26

[15]. http://www.nortonsandblasting.com/weldhealth2.pdf

[16]. McNeilly J.D et al , Soluble transition metals cause the pro-inflammatory effects of welding fumes in vitro, Toxicol Appl Pharmacol, 2004, 196:95-107.

[17]. A. Nastiti et al , Determination of Informal Sector as Urban Pollution Source : Fume Characterization of Small-scale Manual Metal Arc Welding using Factor Analysis in Bandung City, Atom Indonesia Vol. 38 No. 1 (2012) 35 – 42

[18]. http://humanservices.alberta.ca/documents/WHS-PUB_ch032.pdf

Author's Profile

Dr. Pankajkumar holds Master of Engineering (Mechanical from Government Engineering College, Aurangabad and Ph.D., Mechanical Engineering from IIT, Delhi.He has more than 25 years of Experience and at present working as Principal of REC, Raipur.

© 2015, IJARMET All Rights Reserved