# A STUDY ON LUNG ABNORMITY PREDICTORS AMONG WELDERS IN THE AUTOMOTIVE MANUFACTURING INDUSTRIES USING A DECISION TREE MODEL

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In the name of Allah, The Most Gracious, The Most Merciful.

For my beloved parents:

*Hj. Zainal Bakri Ahmad & Hjh. Siti Hasniah Sheikh Othman*

For my beloved family:

*Muhamad Taib Mustapa*

*Annur 'Ishmatul Aufa*

*Muhammad 'Irfanul Affan*

*Muhammad 'Irfanul Amsyar*

*Annur 'Ishmatul Ayra*

*Baby A*

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# ABSTRACT

The risk prediction model has been applied and used widely in various fields, especially in clinical related studies. The transparent reporting of a multivariable prediction model for individual prognosis or diagnosis (TRIPOD) has highlighted that it is crucial to find an important predictor before making a health risk prediction model. Welders are simultaneously exposed to multiple welding fume constituents at once, and the exposure to these fumes contributes to lung problems. To fill this gap, the important predictors of lung abnormalities due to welding fume exposure need to be investigated. This study explored the relationship between a demographic and heavy metal concentration found in the welding areas and the lung abnormalities of welders in automotive industries. A quantitative cross-sectional survey design is used. Individual samples of welding fumes were taken in Plants 1, 2, and 3 to determine the concentration of heavy metal constituents, along with a series of pulmonary function tests, biomarker samples from toenails, and a questionnaire on respiratory problems (exposed group = 48 welders, control group = 42 workers). Descriptive and correlation analyses were used to examine the data. A simple welding- lung assessment (WELA) tree model was created that explained the relationship among the independent variables. The model showed that the concentration of cobalt and aluminium were significant and made a unique contribution to the model as predictors of lung abnormalities in welders in validated test set (ROC/AUC: 0.66, 95% CI: 0.4167–0.9033, sensitivity = 60%, specificity = 20%, precision = 80% and accuracy = 70%). These findings provide new insight into the assessment of lung risk caused by welding fumes using a simple classification tree approach. This groundbreaking study not only identified predictors of lung abnormalities among Malaysian automotive welders but also laid the foundation for a future risk-prediction model, revolutionizing the field of occupational health and safety.

# ABSTRAK

Model ramalan risiko telah diterapkan dan digunakan secara meluas dalam pelbagai bidang, terutamanya dalam kajian berkaitan klinikal. Pelaporan telus bagi model ramalan pelbagai pembolehubah untuk prognosis atau diagnosis individu (TRIPOD) telah menekankan bahawa adalah signifikan untuk mencari peramal penting sebelum membuat model ramalan risiko kesihatan. Pada masa yang sama, pengimpal terdedah kepada sejumlah besar juzuk asap kimpalan, dan pendedahan ini menyumbang kepada masalah paru-paru. Untuk mengisi jurang ini, peramal penting keabnormalan paru-paru akibat pendedahan asap kimpalan perlu dikaji. Kajian ini mengamati hubungan antara demografi dan kepekatan logam berat yang ditemui dalam kawasan kimpalan serta keabnormalan paru-paru pengimpal dalam industri automotif. Reka bentuk tinjauan keratan rentas kuantitatif telah digunakan. Sampel individu asap kimpalan diambil dalam Loji 1, 2, dan 3 untuk menentukan kepekatan juzuk logam berat, bersama-sama dengan satu siri ujian fungsi pulmonari, sampel biopenanda daripada kuku jari kaki, dan soal selidik tentang masalah pernafasan (kumpulan terdedah = 48 pengimpal, kumpulan kawalan = 42 pekerja). Analisis deskriptif dan korelasi digunakan untuk meneliti data. Model pokok penilaian paru-paru kimpalan (WELA) mudah telah dihasilkan bagi menerangkan hubungan antara pembolehubah bebas. Model menunjukkan bahawa kepekatan kobalt dan aluminium adalah signifikan dan memberikan sumbangan unik kepada model sebagai peramal keabnormalan paru-paru pada pengimpal dalam set ujian yang disahkan (ROC/AUC: 0.66, 95% CI: 0.4167–0.9033, kepekaan = 60%, kekhususan = 20%, kepersisan = 80% dan ketepatan = 70%). Penemuan ini memberikan pandangan baharu tentang penilaian risiko paru-paru yang disebabkan oleh asap kimpalan dengan menggunakan pendekatan pokok pengelasan yang mudah. Kajian perintis ini bukan sahaja mengenal pasti peramal keabnormalan paru-paru dalam kalangan pengimpal automotif Malaysia tetapi juga meletakkan asas untuk model ramalan risiko masa depan, merevolusikan bidang kesihatan dan keselamatan pekerjaan.

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| | | |
|---|---|---|
| *%* | - | Percentage |
| *µg/g* | - | Microgram per gram |
| *µg/m$^3$* | - | Microgram per meter cubic |
| *µm* | - | Micrometer |
| *kg* | - | Kilogram |
| *kg/m$^2$* | - | Kilogram per meter square |
| *l/min* | - | Liter per minute |
| *M* | - | Median |
| *m* | - | Meter |
| *m/s* | - | Meter per second |
| *mg/l* | - | Milligram per liter |
| *mg/m$^3$* | - | Milligram per meter cubic |
| *n* | - | Sample |
| *N* | - | Total sample size |
| *$^o$C* | - | Degree Celsius |
| *p* | - | Significant level |
| *ppb* | - | Parts per billion |
| *ppm* | - | Parts per million |
| *ppmv* | - | Parts per million volume |
| *R$^2$* | - | R-squared |
| *τb* | - | Kendall's tau b correlation coefficient |
| *yr* | - | Year |
| *β* | - | Regression Coefficient |
| *AAS* | - | Atomic Absorption Spectroscopy |
| *ACGIH* | - | American Conference of Governmental Industrial Hygienists |
| *Ag* | - | Silver |

| | | |
|---|---|---|
| *Al* | - | Aluminium |
| *AMI* | - | Acute Myocardial Infarction |
| *AOAC* | - | Association of Official Analytical Chemists |
| *As* | - | Arsenic |
| *ASEAN* | - | Association of Southeast Asian Nations |
| *ASR* | - | Age Standardised Rate |
| *ASTM* | - | American Society for Testing and Materials |
| *ATS* | - | American Thoracic Society |
| *ATS-DLD* | - | American Thoracic Society and The Division of Lung Diseases |
| *ATSDR* | - | Agency for Toxic Substances and Disease Registry |
| *AUC* | - | Area Under Curve |
| *Ba* | - | Barium |
| *BAF* | - | Bioaccumulation Ratios |
| *Be* | - | Beryllium |
| *BMI* | - | Body Mass Index |
| *BS* | - | British Standard |
| *Ca* | - | Calcium |
| *CART* | - | Classification and Regression Tree |
| *CAS* | - | Chemical Abstracts Service |
| *Cd* | - | Cadmium |
| *CDC* | - | Centers for Disease Control and Prevention |
| *Ce* | - | Cerium |
| *CHRA* | - | Chemical Health Risk Assessment |
| *CI* | - | Confidence Interval |
| *CIOMS* | - | Council for International Organisation of Medical Sciences |
| *CKD* | - | Chronic Kidney Disease |
| *CLASS* | - | Occupational Safety and Health (Classification, Labelling and Safety Data Sheet of Hazardous Chemicals) Regulations 2013 |
| *Co* | - | Cobalt |
| $CO_2$ | - | Carbon Dioxide |
| *CoP* | - | Codes of Practices |

| | | |
|---|---|---|
| *COPD* | - | Chronic Obstructive Pulmonary Disease |
| *Cr* | - | Chromium |
| *CSI* | - | Chemical Sampling Information |
| *CT* | - | Computerized Tomography |
| *Cu* | - | Copper |
| *CVD* | - | Cardiovascular Disease |
| *DBSCAN* | - | Density-Based Spatial Clustering of Applications with Noise |
| *DNA* | - | Deoxyribonucleic Acid |
| *DOSH* | - | Department of Occupational Safety and Health |
| *ECERDC* | - | East Coast Economic Region Development Council |
| *ERS* | - | European Respiratory Society |
| *ESC* | - | Ever-Smoker Control |
| *ESW* | - | Ever-Smoker Welder |
| *FCAW* | - | Flux Cored Arc Welding |
| *Fe* | - | Iron |
| *FEF* | - | Forced Expiratory Flow |
| *FER* | - | Force Expiratory Ratio |
| $FEV_1$ | - | Forced Expiratory Volume in The First Second |
| $FEV_1/FVC$ | - | Ratio of Forced Expiratory Volume in The First Second per Forced Vital Capacity |
| *FMA 1967* | - | Factories and Machinery Act 1967 |
| *FN* | - | False Negative |
| *FP* | - | False Positive |
| *FPR* | - | False Positive Rate |
| *FVC* | - | Forced Vital Capacity |
| *GHS* | - | Globally Harmonized System for Classification and Labeling of Chemicals |
| *GMA-MS* | - | Gas Metal Arc Welding - Mild Steel Electrode |
| *GMA-SS* | - | Gas Metal Arc Welding - Stainless Steel Electrode |
| *GMAW* | - | Gas Metal Arc Welding |
| *GMM* | - | Gaussian Mixture Model |
| *GTAW* | - | Gas Tungsten Arc Welding |
| *HAC* | - | Hierarchical Agglomerative Clustering |

| | | |
|---|---|---|
| *HE* | - | Health Effect |
| *Hg* | - | Mercury |
| *HIV* | - | Human Immunodeficiency Virus |
| *HMLD* | - | Hard Metal Lung Disease |
| *HMM* | - | Hidden Markov Model |
| *HR* | - | Hazard Rating |
| *IARC* | - | International Agency for Research on Cancer |
| *ICH-GCP* | - | International Conference of Harmonisation Good Clinical Practice Guidelines |
| *ICOP IAQ* | - | Industry Code of Practice on Indoor Air Quality 2010 |
| *ICP* | - | Inductively Coupled Plasma |
| *ICP/DCP-AES* | - | Inductively Coupled Plasma / Direct Current Plasma Atomic Emission Spectroscopy |
| *ICP-MS* | - | Inductively Coupled Plasma Mass Spectrometry |
| *IDLH* | - | Immediately Dangerous to Life or Health |
| *ILO* | - | International Labour Organization |
| *IREC* | - | IIUM Research Ethics Committee |
| *IIUM* | - | International Islamic University Malaysia |
| *ISO* | - | International Organisation for Standardisation |
| *JKKP:GP* | - | Jabatan Keselamatan dan Kesihatan Pekerjaan: Garis Panduan |
| *KM* | - | Kaplan-Meier |
| $LC_{50}$ | - | Lethal Concentration 50 percent |
| *LEV* | - | Local Exhaust Ventilation |
| *LFT* | - | Lung Function Test |
| *LLN* | - | Lower Limit of Normal |
| *LLP* | - | Liverpool Lung Project |
| *LOD* | - | Limit of Detection |
| *LOQ* | - | Limit of Quantification |
| *MCEF* | - | Mixed Cellulose Ester Filter |
| *MFF* | - | Metal Fume Fever |
| *MIG* | - | Metal Inert Gas |
| *Mn* | - | Manganese |

| | | |
|---|---|---|
| *Mo* | - | Molybdenum |
| *MOHR* | - | Ministry of Human Resource |
| *MRL* | - | Minimal Risk Levels |
| *NAP* | - | National Automotive Policy |
| *ND* | - | Non-Detects |
| *Ni* | - | Nickel |
| *NIOSH* | - | National Institute for Occupational Safety and Health |
| *NNCP* | - | New National Car Project |
| *NMAM* | - | NIOSH Manual of Analytical Methods |
| *NSC* | - | Non-Smoker Control |
| *NSW* | - | Non-Smoker Welder |
| $O_2$ | - | Oxygen |
| *OAW* | - | Oxyacetylene Welding |
| *OHD* | - | Occupational Health Doctors |
| *OLD* | - | Occupational Lung Disease |
| *OR* | - | Odd Ratio |
| *OSH* | - | Occupational Safety and Health |
| *OSHA* | - | Occupational Safety and Health Administration |
| *OSHA 1994* | - | Occupational Safety and Health Act 1994 [Act 514] |
| *OSH-MP* | - | Occupational Safety and Health Master Plan |
| *Pb* | - | Lead |
| *PD* | - | Prevalence Difference |
| *PEF* | - | Peak Expiratory Flow |
| *PEL* | - | Permissible Exposure Limit |
| $PM_{10}$ | - | Particulate Matter size 10 micron |
| $PM_{2.5}$ | - | Particulate Matter size 2.5 micron |
| $PM_{1.0}$ | - | Particulate Matter size 1.0 micron |
| *POR* | - | Prevalence Odd Ratio |
| *PR* | - | Prevalence Ratio |
| *REL* | - | Recommended Exposure Limit |
| *rKM* | - | Reverse Kaplan-Meier |
| *ROC* | - | Receiver Operating Characteristic |

| | | |
|---|---|---|
| *ROS* | - | Reactive Oxygen Species |
| *RSD* | - | Residual Standard Deviation |
| *Se* | - | Selenium |
| *SEER* | - | Surveillance, Epidemiology and End Results |
| *SMAW* | - | Shielded Metal Arc Welding |
| *SNP* | - | Single Nucleotide Polymorphism |
| *SOCSO* | - | Social Security Organisation |
| *SOM* | - | Neural Network Self-Organising Map |
| *STEL* | - | Short Term Exposure Limit |
| *SVM* | - | Support Vector Machines |
| *SVR* | - | Support Vector Regression |
| *t-SNE* | - | t-Distributed Stochastic Neighbour Embedding |
| *TB* | - | Torch or Oxyfuel Brazing |
| *Th* | - | Thorium |
| *TIG* | - | Tungsten Inert Gas |
| *TLV* | - | Threshold Limit Value |
| *TN* | - | True Negative |
| *TP* | - | True Positive |
| *TPR* | - | True Positive Rate |
| *TRIPOD* | - | Transparent Reporting of a Multivariable Prediction Model for Individual Prognosis or Diagnosis |
| *TWA* | - | Time Weighted Average |
| *U* | - | Uranium |
| *ULN* | - | Upper Limit of Normal |
| *USECHH* | - | Occupational Safety and Health (Use and Standards of Exposure of Chemicals Hazardous to Health) Regulations 2000 |
| *USEPA* | - | United States Environmental Protection Agency |
| *V* | - | Vanadium |
| *WELA* | - | Welding-Lung Assessment |
| *WHO* | - | World Health Organisation |
| *Zn* | - | Zinc |

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# VITA

Siti Farhana binti Zainal Bakri was born on March 21, 1986, in Kuantan, Pahang. She pursued her degree at the Universiti Malaysia Terengganu (UMT), and graduated with a B. Tech. (Hons) in Environmental Technology in 2009. Upon graduation, she underwent a Process Plant's Safety and Health at Pahang Skills Development Centre (PSDC) and successfully passed the Safety and Health Officer's (SHO) examination under NIOSH. She then worked as a full-time lecturer at the DRB-HICOM University of Automotive Malaysia (DHU) before pursuing her studies at Universiti Putra Malaysia (UPM) under the sponsorship of the Ministry of Higher Education through the MyBrain15 programme in 2013, where she was awarded the M. Eng. (Hons) in Manufacturing Systems Engineering in 2014. In May 2016, she enrolled in the PhD programme in Mechanical Engineering at Universiti Tun Hussein Onn Malaysia (UTHM) and was sponsored by the Ministry of Higher Education through the MyPhD programme. Currently, she has a competent certificate on Train the Trainer by NIOSH, Malaysia (TTT047222-19). She is an associate member of the Malaysia Industrial Hygiene Association (MIHA), the Malaysian Society for Occupational Safety and Health (MSOSH), and the Malaysian Mental Health Association (MMHA). Her research and consulting interests are integrating mechanical engineering with OSH, specialising in occupational health and industrial hygiene. During her research duration, she published eight articles that were related to her PhD research as the main author and two articles as co-author, with at least a SCOPUS index.

## Referred Articles in Journal / Proceeding

1. **Bakri, S. F. Z**., Hariri, A., Ma'arop, N. F., & Hussin, N. S. A. W. (2017). Toenail as Non-invasive Biomarker in Metal Toxicity Measurement of Welding Fumes Exposure - A Review. *IOP Conference Series: Materials Science and Engineering, 165*, 012019. https://doi.org/10.1088/1757-899X/165/1/012019
   *[Indexed by Scopus, Impact Score: 0.48]*.

2. **Bakri, S. F. Z**., Hariri, A., Ismail, M., Abdullah, S., & Kassim, N. I. (2018). Evaluation of Respiratory Symptoms, Spirometric Lung Patterns and Metal Fume Concentrations among Welders in Indoor Air-Conditioned Building at Malaysia. *International Journal of Integrated Engineering, 10*(5). https://doi.org/10.30880/ijie.2018.10.05.017
   *[Indexed by Scopus, Impact Score: 0.743]*.

3. **Bakri, S. F. Z**., Hariri, A., & Ismail, M. (2019). Recent development in lung risk prediction model and its characteristic. *Journal of Physics: Conference Series, 1150*, 012011. https://doi:10.1088/1742-6596/1150/1/012011
   *[Indexed by Scopus, Impact Score: 0.482]*.

4. **Bakri, S. F. Z**., Hariri, A., & Ismail, M. (2020). Occupational Health Risk Assessment of Inhalation Exposure to Welding Fumes. *International Journal of Emerging Trends in Engineering Research, 8*(1.2), 90-97. https://doi:10.30534/ijeter/2020/1381.22020
   *[Indexed by Scopus, Impact Score: 0.218]*.

5. Hariri, A., Mohamad Noor, N., Paiman, N. A., Ahmad Zaidi, A. M., & **Zainal Bakri, S. F**. (2018). Heavy metals found in the breathing zone, toenails and lung function of welders working in an air-conditioned welding workplace. *International Journal of Occupational Safety and Ergonomics: JOSE, 24*(4), 646–651. https://doi.org/10.1080/10803548.2017.1368950
   *[Indexed by Scopus, Impact Factor: 2.538, and Indexed by SCIE/SSCI, Impact Factor: 2.141]*.

**Chapter in Book**

1. **Siti Farhana Zainal Bakri**, Azian Hariri, Nurul Fitriah Nasir. (2020). *Development of Welding Lung Assessment (WELA) as a Prognosis Tool of Lung Impairment from Heavy Metal Exposure among Malaysian Welder*. Recent Development In Industrial

And Indoor Environment Research Studies Series 1, UTHM, 61, ISBN:9789672916437

## Conferences Attended

1. Colloquium on Advanced Mechanics 2016 (CAMS2016) – Paper Presenter. 18 – 19 December 2016. Universiti Tun Hussein Onn Malaysia, Batu Pahat, Malaysia.
2. International Conference on Mechanical & Manufacturing Engineering 2018 (ICME2018) – Paper Presenter. 16 – 17 July 2018. Pulai Spring Resort, Johor Bharu, Malaysia.
3. International Symposium on Safety and Health at Work 2018 (ISOSH 2018) – Paper Presenter. 24 – 25 July 2018. Katerina Hotel, Batu Pahat, Malaysia.
4. Engineering Technology International Conference 2020 (ETIC2020) – Participant. 24 – 25 March 2020. KSL Hotel & Resort, Johor, Malaysia.