TREATMENT OF GALVANIC SLUDGE IN AN ARC THERMAL PLASMA REACTOR

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A thesis submitted in fulfilment of the
requirements for the award of the degree of
Doctor of Philosophy

School of Chemical and Energy Engineering
Faculty of Engineering
Universiti Teknologi Malaysia

MAY 2019

DEDICATION

I hereby dedicate this Ph.D research work to Allah (SWT), my late Father Abdulkarim Ali (Manager), lovely wife (Hafsat Isah Ismail) and my children (Ali, Khadeejah, Sumayyah and Isah)

ACKNOWLEDGEMENT

I am thankful to Allah (SWT) for his mercy and favour upon me and my family. You have always being my strength, my courage and protector. My deepest gratitude goes to my supervisor Associate Professor Dr Mohd Ariffin bin Abu Hassan and co-supervisor Dr Raja Kamarulzaman Bin Raja Ibrahim for their guidance, encouragement and support throughout the Ph.D programme. Special thanks goes to my mother, wife and children for their sacrifice, moral support and prayers. I would also like to appreciate the excellent lecturers of the school of chemical Engineering UTM whom have assisted me in either using their equipment or shaping my final research thesis. I immensely appreciate the contribution of Engr Shuaibu Balogun toward the development of the reactor design. At this moment I cannot forget to commend and appreciate the commitment and willingness to assist of Muhammed Yusuf Shahul Hamid and Nik Norhanani Binti Mohd Ghani during the use of equipment. I'm also thankful to Associate Prof Tuan Amran Tuan Abdullah of centre hydrogen energy UTM for providing gases needed for calibration of equipment, Dr Nadril Hasraf Mat Nayan of Faculty of Engineering Technology, UTHM for assisting to understand Inductive couple plasma optical emission spectrometry analysis and Dr Muhammad Abbas Zaini of Centre of Lipids Engineering and Applied Research.

I'm indebted to Mr Mohd Sauffie Bin Mansor and Nursyahirah Binti Mustapha of Plasma Technology and Optical Diagnostic laboratory, faculty of science UTM. I am also grateful to wonderful brother and research team mate Abubakar Ali Mohammad and my colleagues in University of Abuja. Finally, I would thank and acknowledge the University of Abuja management for approving my absence from work and given me access to Tertiary Education Trust Fund (TETFUND) scholarship.

ABSTRACT

The performance of arc thermal plasma in treating galvanic sludge was investigated. The inductively coupled plasma optical emission spectrometry analysis conducted to characterise the raw galvanic sludge reveals the presence of chromium (Cr), copper (Cu), iron (Fe), magnesium (Mg), manganese (Mn), lead (Pb) and zinc (Zn). Product gas was measured at varying applied current of 170 A to 190 A and residence time of 2 to 5 minutes. The fourier transform infrared spectrometry analysis of the gaseous product identified the presence of carbon monoxide (CO), carbon dioxide (CO_2), methane (CH_4), ethene (C_2H_4), ethyne (C_2H_2) and water (H_2O) in different concentrations. In general, the trend in CO and CO_2 concentrations initially shows an increase as the applied current was increased and thereafter decreases. Low concentrations of hydrocarbon were persistent, which is due to the low amount of hydrocarbon in the galvanic sludge. From the analysis the concentration of CH_4, C_2H_4 and C_2H_2 revealed were 46 ppm, 39 ppm and 73 ppm respectively. A quadratic model for CO concentration in the gaseous product was developed. The developed model using the response surface methodology showed a good fit with correlation coefficients of 99.63%. The optimum operating conditions for the treatment were 170.4 A, 20.13 L/min and 3.12 minutes for applied current, plasma gas flow rate and residence time respectively. The optimum response of CO obtained from the optimization of the reaction system was 1622 ppm with desirability of 1. Treatment at applied current of 170 A revealed metals were either within the toxicity leaching characteristic limit or not detected. The concentration of the metals found in the treated sludge were Cr (0.410 mg/l), Cu (0.350 mg/l), Fe (4.0 mg/l), Zn (0.8 mg/l) while magnesium, nickel and lead were not detected. The applied current of 170 A represents the minimum applied current sufficient for immobilisation of metals contained in the galvanic sludge. The economic analysis of arc thermal plasma for treatment of galvanic sludge reveals a profit margin of RM 5.89 per kg of sludge. The cost of arc thermal plasma treatment is RM 6.49 which is far cheaper than the cost of treatment (RM 27.811) using incineration. Furthermore, a positive return on investment of 5.81% would be realized in the fifth year of operation. Thermal plasma treatment technique is, therefore, a viable alternative method for treating galvanic sludge.

ABSTRAK

Prestasi plasma arka haba dalam merawat enapcemar galvanik dikaji. Analisis spektromeri pelepas plasma optik induktif yang dilaksanakan untuk mencirikan enapcemar galvanik mentah mendedahkan kehadiran kromium (Cr), tembaga (Cu), besi (Fe), magnesium (Mg), mangan (Mn), plumbum (Pb) dan zink (Zn). Produk gas diukur pada arus pelbagai dari 170 A hingga 190 A dan residence time 2 - 5 minit. Analisis transformasi fourier inframerah bagi produk gas menunjukkan kehadiran karbon monoksida (CO), karbon dioksida (CO_2), metana (CH_4), etana (C_2H_4), etyne (C_2H_2), dan air (H_2O) dalam kepekatan yang berbeza. Secara umumnya, trend kepekatan CO dan CO_2 pada awalnya menunjukkan kenaikan apabila arus yang digunakan meningkat dan kemudian berkurangan. Kepekatan rendah hidrokarbon adalah berterusan, disebabkan oleh jumlah hidrokarbon yang rendah dalam enapcemar galvanik. Dari analisis kepekatan CH_4, C_2H_4 dan C_2H_2 menunjukkan masing-masing 46 ppm, 39 ppm dan 73 ppm. Model kuadratik untuk kepekatan CO dalam produk gas telah dijana. Model yang dijana menggunakan kaedah sambutan permukaan menunjukkan kelekapan baik dengan pekali korelasi sebanyak 99.63%. Keadaan operasi optimum bagi rawatan adalah masing-masing pada 170.4 A, 20.13 L/min dan 3.12 minit bagi arus yang digunakan, kadar aliran gas plasma dan masa mastautin. Tindak balas optimum CO yang diperoleh daripada pengoptimuman sistem tindakbalas adalah 1622 ppm dengan keinginan 1. Rawatan pada arus 170 A menunjukkan logam berada dalam had prosedur penyingkiran ciri toksik atau tidak dikesan. Kepekatan logam yang ditemukan dalam enapcemar yang telah dirawat adalah Cr (0.410 mg/l), Cu (0.350 mg/l), Fe (4.0 mg/l), Zn (0.8 mg/l) manakala magnesium, nikel dan plumbum tidak dikesan. Arus pada 170 A mewakili arus minimum yang diperlukan untuk menghalang pemindaan logam yang terdapat dalam enapcemar galvanik. Analisis ekonomi plasma arka haba untuk rawatan enapcemar galvanik menunjukkan margin keuntungan sebanyak RM 5.89 per kg enapcemar. Kos rawatan plasma arka haba adalah RM 6.49 yang jauh lebih murah daripada kos rawatan (RM 27.811) menggunakan pembakaran. Di samping itu, pulangan positif pelaburan sebanyak 5.81% boleh direalisasikan pada tahun kelima operasi. Teknik rawatan plasma merupakan kaedah alternatif yang sesuai untuk merawat enapcemar galvanik.

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LIST OF ABBREVIATIONS

A	-	Ampere
Ar	-	Argon
AAS		Atomic Absorption Spectrophotometer
ASTM	-	American Standard Test Method.
CO	-	Carbon monoxide
Cu	-	Copper
Ba	-	Barium
CO_2	-	Carbondioxide
CH_4	-	Methane
C_2H_4	-	Ethane
C_2H_2	-	Ethylene
Cr	-	Chromium
DC	-	Direct Current
EC	-	Energy Consumption
EDX	-	Energy Dispersive Spectroscopy
EPA	-	Environmental Protection Agency
FC	-	Fixed Carbon
Fe	-	Iron
FE-SEM	-	Field Emission Scanning Electroscope Microscopy
FTIR	-	Fourier Transformed Infrared Spectroscopy
FWW	-	Forestry Wood Waste
GCV	-	Gross Calorific Value
H_2	-	Hydrogen
H_2S	-	Hydrogen Sulphide
He	-	Helium
IBA	-	Incineration Bottom Ash
IC	-	Inorganic Carbon
ID	-	Internal Diameter
ICP-OES	-	Inductively Coupled Plasma Optical Spectrometry
LC	-	Leachate Concentration

Mrs	-	Mass Of Raw Galvanic Sludge
M_S	-	Mass Of Solid Product
Mn	-	Manganese
Mg	-	Magnesium
MJ	-	Mega Joule
MSW	-	Municipal Solid Waste
MT	-	Metric Tonne
Ni	-	Nickel
NO	-	Nitric Oxide
NO_2	-	Nitrogen Dioxide
NO_X	-	Oxides Of Nitrogen
OD	-	Outside Diameter
P	-	Power
PAED	-	Pulsed Arc Electrohydraulic Discharge
Pb	-	Lead
PARF	-	Plasma Application Research Facility
ppm	-	Part Per million
RGS	-	Raw galvanic sludge
SEM	-	Scanning Electron Microscopy
Si	-	Silicon
SO_2	-	Sulphur (IV) Oxide
SW	-	Scheduled Waste
TC	-	Total Carbon
TCLP	-	Toxicity Characteristics Leaching Procedure
TGA	-	Thermogravimetric Analysis
TIG	-	Tungsten Inert Gas
TOC	-	Total Organic Carbon
V_{RS}	-	Volume of Raw Galvanic Sludge
VM	-	Volatile Matter
WPS	-	Wet Paper Sludge
WPC	-	Westinghouse Plasma Corporation
WW	-	Waste Water

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CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Galvanic sludge is generated in the process of applying a protective zinc coating to iron or steel so as prevent rusting and improve the lifespan of metallic material. The method of galvanizing mostly applied is the hot dip galvanizing, whereby Zinc coating is produced on the material by immersion of material in a bath of molten zinc at a temperature of about 450 ^{o}C. This is applied for different type of material ranging from small metal piece to very large structural shapes. The constituent of the galvanic sludge depend on the installed process, but basically it is a heavy metal (chromium, nickel, zinc, cadmium, tin, lead, copper, etc.) laden waste that is toxic and hazardous to the environment (Nikolay and Maria, 2017a; Rossini and Bernardes, 2006).

Majorly employed thermal method for treatment of sludge includes carbonization of dehydrated sludge (Katoh *et al.*, 2005), low temperature pyrolysis (Shen and Zhang, 2005; Wang *et al.*, 2007) and gasification of dried sludge (Dogru *et al.*, 2002; Murakami *et al.*, 2006; Werle, 2015a, 2015b) but these technologies are associated with the production of secondary solid waste and/or product gas containing CO_2, dioxins and furans. Most recently thermal plasma technology which is a short residence time process and environmentally friendly waste management technique is been applied to handle large volume of hazardous industrial sludge. Plasma technology basically involves the creation of a sustained electrical arc by passing electric current through a gas in a process referred to as electrical breakdown. Since electrical resistivity exist across the system, significant heat is generated, which strips away electrons from the gas molecules resulting in an ionised gas stream, or plasma.

Air is the most common gas used, but several inert gases such nitrogen (N_2), Helium (He) and Argon (Ar) have been widely used (Hrabovsky, 2002; Watanabe and Shimbara, 2003). In order for air to conduct electricity, it must be subjected to a large differential in electrical potential. This is done between two electrodes which are separated by air. When this potential is large enough, electrons can be pulled from the normally neutral molecules in the air. These electrons then move with the electric field and impact other molecules, releasing more free electrons at an exponential rate. This phenomenon is called an electron cascade and once enough electrons are moving with the electric field, an arc is created between the electrodes. At temperatures of about 3000 ^{o}C gas molecules lose electrons and become ionised (Auciello and Flamm, 1989). There are basically two types of plasma for industrial processes: thermal or (equilibrium) plasmas and non-equilibrium plasmas (Boulos, 1991; Kogelschatz, 2004).

Thermal plasma has advantages of high temperature, high intensity, non-ionizing radiation and high energy density. According to Tandero *et al*, (2006) thermal plasmas can reach temperatures of above 20,000 K but the equilibrium temperature utilised in treatment of the waste could be far less. The advantages of thermal plasmas are employed in many industrial applications. Plasma gases were used to simulate high temperature conditions similar to those when missiles re-enter the atmosphere. Today thermal plasma technology covers a wide spectrum of applications such as thermal plasma coating techniques (plasma spraying and plasma chemical vapor deposition), thermal plasma synthesis of fine powders, thermal plasma metallurgy and thermal plasma waste destruction.

According to Heberlin and Murphy (2008) the approach for plasma treatment of different types of waste may consist of the following; thermal break down of chemical components without oxidation which is called plasma pyrolysis, the incomplete oxidation of organic fraction of waste and generation of syngas and other gases which can be used to generate electric power or drive steam turbines known as plasma gasification, compaction and vitrification of solid wastes by gasifying organic material, melting inorganic material and binding hazardous metals in a ceramic matrix (e.g. a silicate). The integration of plasma pyrolysis, compaction and vitrification process or a combination of plasma gasification, compaction and vitrification can be applied for solids with high fractions of organic.

In this research, arc thermal plasma was applied to treat galvanic sludge. A plasma field created by directing an electric field through a low pressure gas stream generate high temperatures. The intense high temperature of between 1700 ^{o}C and 2200 ^{o}C achieved at varying applied current and time can be used to dissociate waste into their atomic element in the reaction chamber. Heat generated from the plasma torch can melt and vitrify the inorganic portion of the galvanic sludge while the organic components can be vaporized and decomposed by the intense heat.

1.2 Problem Statement

Large volume of heavy metal containing sludges is generated globally, and galvanic sludge arising from galvanizing processes is a major contributor. Galvanic sludge is a category of Scheduled Waste (SW) refer to as SW105 in Malaysia that is hazardous and no longer allowed to be disposed directly to landfill. The sludge majorly constitutes heavy metals (Emine *et al.*, 2013; Kobya *et al.*, 2015). Apart from the presence of heavy metal found in the sludge, it also contains, surfactants, oil and grease, hydroxides and hydrate oxides.

The disposal of untreated or not properly managed heavy metal containing sludge such as galvanic sludge has various environmental, human and health effect. Excess levels of heavy metals introduced to soil by sludge can lead to elevated uptake of heavy metals by plants. This may cause irreparable damage to the plants. It can also affect human health upon the consumption of the plants since these plants consist of accumulated levels of the heavy metals within their tissues. The heavy metal can also lead to underground water pollution. Incineration is the most common treatment method applied to hazardous waste such as galvanic sludge. This method reduce the sludge volume for final disposal, however it has a lot of drawback. It does not completely destroy the metals in the sludge, which means that the metals in the sludge will remain and still pollute the environment. It also generate hazardous fly ash and bottom ashes that requires further treatment.(Cedzynska *et al.*, 1999; Chun-Teh *et al.*, 2007). It also generate fly ash and bottom fly ash that are not free of toxic substances which will still require landfilling. The chemical methods of treatment has the major problem of waste separation and large consumption of reagents while ion exchange is only effective when dealing with low concentration of heavy metals (Nikolay and Maria, 2017b). Therefore, there is the need for a treatment options such as thermal plasma that will convert the remnant waste into inert or harmless material.

Thermal plasma technology has the ability to efficiently detoxify hazardous waste such as galvanic sludge. This has been proven by previous researches conducted by (Bień *et al.*, 2013; Chang *et al.*, 2008; Cubas *et al.*, 2014b; Gomez *et al.*, 2009; Li *et al.*, 2012; Li *et al.*, 2015a; Szente *et al.*, 1998) have proven thermal plasma technology to be an efficient means of detoxification of the sludge but notwithstanding the treatment process comes along with gaseous product (Syngas) that has gotten no research attention. The only researches so far conducted on treating galvanic sludge using thermal plasma technology focused on inertisation and vitrification (Cubas *et al.*, 2014b). Presently, there is no documented research investigation on the effect of process variable on the gaseous product from thermal plasma treatment of galvanic sludge. It is therefore the intention of this research to investigate the effect of process variable on gaseous product and level of inertisation of slag (solid product) obtained from treatment of galvanic sludge. The immobilisation of the metals in the solid product can be achieved as a result of the exposure of the galvanic sludge to the high temperature from thermal plasma. The high temperature renders non-heavy metals which are non-volatile species chemically bonded and forms a non-leachable solid matrix.

1.3 Research Aim and Objectives

i. To characterised galvanic sludge prior to thermal plasma treatment.
ii. To determine the effect of applied current and residence time on solid and gaseous product.

iii. To optimize CO in the gaseous product using surface response methodology (RSM).

iv. To conduct economic analysis on the treatment of galvanic sludge in an arc thermal plasma.

1.4 Scope of Research

The scope of this research includes the collection of galvanic sludge from KISWIRE Sdn Bhd. The characterization of the galvanic sludge to determine the moisture, volatiles, ash content, fixed carbon, total organic carbon (TOC), elemental composition and morphological structure. The designing and fabrication of the arc plasma reactor. The analysis of the solid and gaseous to determine the total organic compound, heavy metal composition, leachability and composition of the gaseous product. Finally, Optimization and economic analysis of the laboratory arc thermal plasma.

1.5 Significance and Contribution of the Research

Recently, galvanic sludges are treated in incinerators in Malaysia. This method does not completely immobilise heavy metals. It also generate fly and bottom ashes that are toxic to the environment. It also generate fly ash and bottom ashes that requires further treatment. Thermal plasma technology can efficiently treat galvanic sludges. It can transform the sludge into non-toxic and harmless materials. Investigations on effect of applied voltage and residence on the composition of gaseous product from treatment of galvanic sludge in thermal plasma will provide data and information that will help safeguard human and the environment against toxic pollution arising from galvanic industries. The developed thermal plasma system is expected when upgraded to pilot or industrial scale to serve as an alternative treatment technique which does not give rise to secondary pollutant and reduce the large volume of heavy metal containing sludge and other related hazardous waste such as Scheduled Waste in Malaysia.

1.6 Organisation of Study

This research work conducted consist of five chapters as follows:

Chapter One is the introduction: The chapter covers introductory background of the research. It also critically outline the aim and objectives, the scope and significance of the research.

Chapter Two is the literature review: The chapter, basically focus on the relevant previous researches to the study area. The principle of thermal plasma technology and its application to waste treatment.

Chapter Three is the methodology of research: This chapter covers procedure on sample collection and preparation obtained from KISWIRE Sdn Bhd, description of process equipment, methods of characterisation of galvanic sludge, procedure on thermal plasma treatment of galvanic sludge in thermal plasma system. It also entails characterisation of gaseous and solid product.

Chapter Four is results and discussion: This chapter present results and elaborate discussion of experiment and analysis done in this research. It documents results and discussion on characterisation of galvanic sludge and products from thermal plasma system, effect of applied current and residence time on the composition of gaseous products, leaching test analysis, optimisation and economic analysis of the treatment process.

Chapter Five is the Conclusion and recommendation: In this chapter important inferences were reached based on the results and the discussion. Possible Recommendation on future work was suggested.

REFERENCES

Abdullahi, M. E.Abu Hassan, M. A.Zainon-Noor, Z. and Ibrahim, R. K. (2016). Integrated air stripping and non-thermal plasma system for the treatment of volatile organic compounds from wastewater: statistical optimization. Desalination and Water Treatment, 57(34), 16066-16077.

Affam, A. C. and Chaudhuri, M. (2014). Optimization of Fenton treatment of amoxicillin and cloxacillin antibiotic aqueous solution. Desalination and Water Treatment, 52(10-12), 1878-1884.

AGA. (2011). Zinc coating: A Comparative Analysis of Process and Performance Characteristics. America: American Galvanizers Association.

Ahmadipourroudposht, M.Fallahiarezoudar, E.Yusof, N. M. and Idris, A. (2015). Application of response surface methodology in optimization of electrospinning process to fabricate (ferrofluid/polyvinyl alcohol) magnetic nanofibers. Materials Science and Engineering: C, 50, 234-241.

Al-Mayman, S.Ibrahim, A.Abdullah, A.Imed, G. and Saud, B. (2017). Treatment of fly ash from power plants using thermal plasma. Beilstein J. Nanotechnol., 8, 1043-1048.

Alvim-Ferraz, M. C. and Afonso, S. A. (2005). Incineration of healthcare wastes: management of atmospheric emissions through waste segregation. Waste Manag, 25(6), 638-648.

Amrate, S.Akretche, D. E.Innocent, C. and Seta, P. (2005). Removal of Pb from a calcareous soil during EDTA-enhanced electrokinetic extraction. Science of The Total Environment, 349(1), 56-66.

André, R.Pinto, F.Franco, C.Dias, M.Gulyurtlu, I.Matos, M. A. A. and Cabrita, I. (2005). Fluidised bed co-gasification of coal and olive oil industry wastes. Fuel, 84(12–13), 1635-1644.

Andreola, F.Barbieri, L.Bondioli, F.Cannio, M.Ferrari, A. and Lancellotti, I. (2008). Synthesis of chromium containing pigments from chromium galvanic sludges. Journal of Hazardous Materials, 156(1), 466-471.

Anyaegbunam, F. N. C. (2014). Hazardous Waste Vitrification by Plasma Gasification Process. OSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT), 8(3), 15-19.

Auciello, O. and Flamm, L. D. (1989). Plasma Diagnostics, Plasma-materials Interactions Vol. vol. 1.

Baek, K.Kim, D. H.Park, S. W.Ryu, B. G.Batjargal, T. and Yang, J. S. (2009). Electrolyte conditioning-enhanced electrokinetic remediation of arsenic-contaminated mine tailing. J Hazard Mater, 161(1), 457-462.

Bajpai, P. (2014). Management of Pulp and Paper Mill Waste: Springer International Publishing.

Barakat, M. A. (2011). New Trends in Removing Heavy Metals from Industrial Wastewater. Arabian Journal of Chemistry, 4(4), 361-377.

Bashir, M. J. K.Amr, S. S. A.Aziz, S. Q.Aun, N. C. and Sethupathi, S. (2015). Wastewater treatment processes optimization using response surface methodology (RSM) compared with conventional methods: review and comparative study. Middle-East Journal of Scientific Research, 23(2), 244-252.

Bednarik, V.Vondruska, M. and Koutny, M. (2005). Stabilization/solidification of galvanic sludges by asphalt emulsions. Journal of Hazardous Materials, 122(1), 139-145.

Bender, O.Schroeter, R.Garcia, M. and Szente, R. (1998). Treating electroplating residues with thermal plasmas. JOM, 50(7), 32-35.

Bezerra, M. A.Santelli, R. E.Oliveira, E. P.Villar, L. S. and Escaleira, L. A. (2008). Response surface methodology (RSM) as a tool for optimization in analytical chemistry. Talanta, 76(5), 965-977.

Bhargava, P.Gupta, N.Vats, S. and Goel, R. (2018). Health Issues and Heavy Metals. Austin J Environ Toxicol., 3(1), 1-7.

Bianchini, A.Bonfiglioli, L.Pellegrini, M. and Saccani, C. (2015). Sewage sludge drying process integration with a waste-to-energy power plant. Waste Manage, 42, 159-165.

Bień, J.Celary, P.Morzyk, B.Sobik-Szołtysek, J. and Wystalska, K. (2013). Effect of additives on heavy metal immobilization during vitrification of tannery sewage sludge. Environment Protection Engineering, 39(2), 33--40.

Bing, G.Yi, D.Yuanyi, Y.Swee, N., TQianni, L. and Weizhong, Y. (2017). Solidification and Biotoxicity Assessment of Thermally Treated Municipal Solid Waste Incineration (MSWI) Fly Ash. Int. J. Environ. Res. Public Health, 14(6), 1-10.

Biswajit, R. (2012). Thermal plasma treatment of mobile phone waste under reduced condition. International Journal of Environmental Sciences, 2. No. 4(4), 1-8.

Borowski, G. (2015). Using Vitrification for Sewage Sludge Combustion Ash Disposal Pol. J. Environ. Stud., 24(5), 1889-1896.

Boulos, M. I. (1991). Thermal plasma processing. IEEE Trans Plasma Sci, 19, 1078-1089.

Bradl, H. B. (2005). Sources and origin of heavy metals Heavy metals in the Environment. Department of Environmental Engineering, University of Applied Sciences Trier, Umwelt-Campus Birkenfeld.

Bradley, N. (2007). The response surface methodology. (Master of Science), Indiana University South Bend.

Brunner, C. R. (1989). Industrial sludge waste incineration. Environmental Progress, 8(3), 163-166.

Byun, Y.Moohyun, C.Soon, M. H. and Jaewoo, C. (2011). Thermal Plasma Gasification of Municipal Solid Waste (MSW).

Byun, Y.Namkung, W.Cho, M.Chung, J. W.Kim, Y.Lee, J. H.Lee, C. and Hwang, S. M. (2010). Demonstration of thermal plasma gasification/vitrification for municipal solid waste treatment. Environmental Science & Technology, 44(17), 6680-6684.

Carter, G. W. and Tsangaris, A. (1994). Municipal solid waste disposal process: Google Patents.

Carter, G. W. and Tsangaris, A. V. (1995). Plasma Gasification of Municipal Solid Waste Paper presented at the Environmental technologies: plasma systems and applications, Georgia Institute of Technology / University of Bordeaux I.

Cedzynska, K.Kolacinski, Z.Izydorczyk, M. and Sroczynski, W. (1999). Plasma vitrification of waste incinerator ashes,in: International Ash Utilization Symposium. Centre for Applied Energy Research, University of Kentucky.

Celary, P. and Sobik-Szołtysek, J. (2014). Vitrification as an alternative to landfilling of tannery sewage sludge. Waste Manag, 34(12), 2520-2527.

Cerqueira, N.Vandensteendam, C.Baronnet, J. M. and Girold, C. (2004). Heavy metals volatility during thermal plasma vitrification of mineral waste. Environ. Eng. Sci., 21, 83–92.

Chang, J. S.Li, O. L. and Guo, Y. (2008). Thermal plasma treatment of storm water detention pond sludge. Journal of pure and applied chemistry, 80, 1993-2002.

Changming, D.Chao, S.Gong, X.Ting, W. and Xiange, W. (2018). Plasma methods for metals recovery from metal–containing waste. Waste Management, 77, 373-387.

Charlotee, E. (1992) An anectodal history of the galvanizing industry. American Galvanizers Association.

Chibuike, G. U. and Obiora, S. C. (2014). Heavy Metal Polluted Soils: Effect on Plants and Bioremediation Methods. Applied and Environmental Soil Science, 2014,

Choi, S.Li, T.Watanabe, T. and Nakayama, T. (2013). Numerical Analysis of Temperature Distribution in the Long DC Arc Thermal Plasma for Waste Treatment. Journal of Chemical Engineering of Japan, 46(3), 201-208.

Choi, S. and Watanabe, T. (2012). Decomposition of 1-Decanol Emulsion by Water Thermal Plasma Jet. IEEE Transactions On Plasma Science, 40(11).

Chun-Teh, L.W e n-Jhy, L.Ku o-Lin, H.Sheng-F e n g, F. and Y i-C h i e h, L. (2007). Vitrification of Chromium Electroplating Sludge. Environ. Sci. Technol.(41), 2950-2956.

Conesa, J. A.Marcilla, A.Moral, R.Moreno-Caselles, J. and Perez-Espinosa, A. (1998). Evolution of gases in the primary pyrolysis of different sewage sludges. Thermochim. Acta, 313(1), 63-73.

Corella, J. and Toledo, J. M. (2000). Incineration of doped sludges in fluidized bed. Fate and partitioning of six targeted heavy metals. I. Pilot plant used and results. J Hazard Mater, 80(1–3), 81-105.

Cubas, A. L. V.de Medeiros Machado, M.de Medeiros Machado, M.Gross, F.Magnago, R. F.Moecke, E. H. S. and Gonçalvez de Souza, I. (2014a). Inertization of heavy metals present in galvanic sludge by DC thermal plasma. Environmental Science & Technology, 48(5), 2853-2861.

Cubas, A. L. V.Machado, M. D.-M.Machado, M. D.-M.Dutra, A. R. D.-A.Moecke, E. H. S.Fiedler, H. D. and Bueno, P. (2015a). Final treatment of spent batteries by thermal plasma. Journal of Environmental Management, 159, 202-208.

Cubas, A. L. V.Machado, M. D.-M.Machado, M. D.-M.Gross, F.Magnago, R. F.Moecke, E. H. S. and De-Souza, I. G. (2014b). Inertization of Heavy Metals Present in Galvanic Sludge by DC Thermal Plasma. Environmental Science & Technology, 48(5), 2853-2861

Cubas, A. L. V.Machado, M. M.Machado, M. M.Dutra, A. R. A.Moecke, E. H. S.Fiedler, H. D. and Bueno, P. (2015b). Final treatment of spent batteries by thermal plasma. Journal of Environmental Management, 159(Supplement C), 202-208.

Deegan, D.Chapman, C.Ismail, S. A.Wise, M. L. H. and Ly, H. (2006). The thermal treatment of hazardous wastes materials using Plasma Arc technology, in: IMechE Conference. Delivering Waste Solutions—Balancing Targets, Incentives and Infrastructure IMechE London, 9.

DOE. (2005). Environmental Quality (Schedule Wastes) Regulation 2005 Malaysia: Department of Environment, Malaysia.

DOE. (2009). Environmental Quality (control of pollution from solid waste transfer station and landfill) Regulation, under Malaysia Environmental Quality Act 1974.

Dogru, M.Midilli, A. and Howarth, C. R. (2002). Gasification of sewage sludge using a throated downdraft gasifier and uncertainty analysis. Fuel Processing Technology, 75(1), 55-82.

Donald, R. M. (2000). waste incineration and public health. constitution avenue, New York, Washington DC: National Academy press.

Ducharme, C. and Themelis, N. (2010, May 11-13, 2010). Analysis of Thermal Plasma - Assisted Waste-to Energy Processes. Paper presented at the 18th Annual North American Waste-to-Energy Conference, Orlando, Florida, USA.

Duret, A.Maréchal, F. and Friedli, C. (2005). Process design of Synthetic Natural Gas (SNG) production using wood gasification. Journal of Cleaner Production, 13(15), 1434-1446.

Emine, E. O.Cemal, E. G.Sinan, G.Huseyin, K. O.Naim, S.Serdar, A. and Nilgun, B. (2013). Comparative metal (Cu, Ni, Zn, total Cr, and Fe) removal from galvanic sludge by molasses hydrolysate. J Chem Technol Biotechnol, 88, 2046–2053.

Fakhreddine, O.Ahmed, K. and Jean Marie, C. (2009). Production from Propane Using Atmospheric Non-thermal Plasma. Plasma Chemistry and Plasma Processing, Springer Verlag, 29, 119 -130.

Fallahiarezoudar, E.Ahmadipourroudposht, M.Yusof, N. M.Idris, A. and Ngadiman, N. H. A. (2017). 3D Biofabrication of Thermoplastic Polyurethane (TPU)/Poly-l-lactic Acid (PLLA) Electrospun Nanofibers Containing Maghemite (γ-Fe2O3) for Tissue Engineering Aortic Heart Valve. Polymers, 9(11), 584.

Fashola, M.Ngole-Jeme, V. and Babalola, O. (2016). Heavy metal pollution from gold mines: Environmental effects and bacterial strategies for resistance. Int. J. Environ. Res. Public Health., 13.

Franco, C.Pinto, F.Gulyurtlu, I. and Cabrita, I. (2003). The study of reactions influencing the biomass steam gasification process. Fuel, 82(7), 835-842.

Frederic, F.Christophe, R.Vandad-Julien, R. and Laurent, F. (2013). Waste Gasification by Thermal Plasma: A Review. Waste and Biomass Valorization, 4(3), 421-439.

Frugier, P.Girold, C.Megy, S.Vandensteendam, C.Ershov-Pavlov, E. A. and Baronnet, J. (2000). OES use and vaporization modeling for fly-ash plasma vitrification. Plasma Chemistry and Plasma Processing, 20, 65-86.

GAA. (2012). The Basics of Hot Dip Galvanized Steel. First and Last Line of Defence. In 1 (Ed.). australia.

Galas, D.Kalembkiewicz, J. and Sitarz-Palczak, E. (2016). Physicochemistry, morphology and leachability of selected metals from post-galvanized sewage sludge from screw factory in Łańcut, SE Poland. Contemporary Trends in Geoscience, 5(2), 83-91.

Gary, W. D. (2015). Continous hot dip galvanizing-process and products. GALVINFO CENTER. A proramme for the international zinc association.

Gavrilescu, D. (2008). Energy From Biomass in Pulp and Paper Mills. Environmental Engineering and Management Journal, 7(5), 537-546.

Gomez, E.Rani, D. A.Cheeseman, C. R.Deegan, D.Wise, M. and Boccaccini, A. R. (2009). Thermal plasma technology for the treatment of wastes: a critical review. Journal of Hazardous Materials, 161(2), 614-626.

Gray, L. (2014). Plasma Gasification as a Viable Waste-to-Energy Treatment of Municipal Solid Waste: Solid and Hazardous Waste Prevention and Control Engineering.

Haji, A.Mousavi-Shoushtari, A.Mazaheri, F. and Tabatabaeyan, S. E. (2016). RSM optimized self-cleaning nano-finishing on polyester/wool fabric pretreated with oxygen plasma. The Journal of The Textile Institute, 107(8), 985-994.

Haji, A. S., A. M. and Abdouss, M. . (2014). RSM optimization of plasma initiated grafting of acrylic acid onto polypropylene nonwoven. Journal of Macromolecular Science, 51(1), 76-87.

Haugsten, K. E. and Gustavson, B. (2000). Environmental properties of vitrified fly ash from hazardous and municipal waste incineration. Waste Manage(20), (2-3).

He, Y. D.Zhai, Y. B.Li, C. T.Yang, F.Chen, L.Fan, X. P.Peng, W. F. and Fu, Z. M. (2010). The fate of Cu, Zn, Pb and Cd during the pyrolysis of sewage sludge at different temperatures. Environmental Technology, 31(5), 567-574.

Heberlin, J. and Murphy, A. B. (2008). Topical review:Thermal plasma waste treatment. Journal of Applied physics, 41, 1-20.

Holger, E.Hirofumi, S.Toshihiko, M.Nobutoshi, T. and L, A. (2001). State of the art treatment processes for municipal solid waste incineration residues in Japan. Environmental Science & Technology, 35(7), 1531-1536

Hrabovsky, M. (2002). Generation of thermal plasmas in liquid-stabilized and hybrid dc-arc torches. Pure Appl. Chem, 74, 429-433.

Huang, H. and Tang, L. (2007). Treatment of organic waste using thermal plasma pyrolysis technology. Energy Conversion and Management, 48, 1331-1337.

Huang, H.Tang, L. and Wu, C. Z. (2003). Characterization of gaseous and solid product from thermal plasma pyrolysis of waste rubber. Environ Sci Technol, 37(19), 4463-4467.

IAEA-TECDOC. (2006). Application of Thermal Technologies for Processing of Radioactive Waste. Waste Technology Section, International Atomic Energy Agency.

Inaba, T. and Iwao, T. (2000). Treatment of waste by dc arc discharge plasmas. IEEE Trans. Dielectrics Electrical Insulation, 7, 684-692.

Inaba, T.Nagano, M. and Endo, M. (1999). Investigation of plasma treatment for hazardous wastes such as fly ash and asbestos. Electrical Eng. Jpn, 126, 73-82.

Iwao, T. and Inaba, T. (2002). Plasma length on characteristics of DC argon plasma torch arc. Vacuum, 65(3), 299-304.

Iwao, T. and Yumoto, M. (2006). Portable application of thermal plasma and arc discharge for waste treatment, thermal spraying and surface treatment. IEEJ Transactions on Electrical and Electronic Engineering, 1(2), 163-170.

Janajreh, I.Raza, S. S. and Valmundsson, A. S. (2013). Plasma gasification process: Modeling, simulation and comparison with conventional air gasification. Energy Conversion and Management, 65(Supplement C), 801-809.

Jia, H.Gao, Z.Ma, Y.Zhong, C.Xie, Y.Zhou, H. and Wei, P. (2013). Optimization of phenoxazinone synthase production by response surface methodology and its application in Congo red decolourization. Electronic Journal of Biotechnology, 16(5), 2-2.

John, W. K. (2006). Zinc Coatings: Steel's Corrosion Inhibitor American Galvanizers Association.

Junoh, H.Yip, C. and Kumaran, P. (2016). Effect on Ca (OH) 2 pretreatment to enhance biogas production of organic food waste. Paper presented at the IOP conference series: earth and environmental science.

Kaldas, A.Carabin, P.Picard, I.Chevalier, P. and Holcroft, G. (2007). Treatment of ship sludge oil using a plasma arc waste destruction system (PAWDS). Paper presented at the IT3'07 Conference, Phoenix AZ.

Kaldas, A.Theodora, A. and Peter, T. (2003). Optimization of the marine plasma waste destruction technology. Paper presented at the IT3'03 Conference., Orlando, Florida.

Kamolwan, T. (2009). Effects of heating and copper diffusion on feldspar GIA Laboratory, Bangkok.

Kanwal, R.F., F.Iqra, W. and Muhammad, S. H. A. (2017). Prevalence of exposure of heavy metals and their impact on health consequences. Cellular biochemistry, 119(1), 157-184.

Kanwal, R.Fiza, F.Iqra, W. and Muhammad, S. H. A. (2018). Prevalence of exposure of heavy metals and their impact on health consequences. J Cell Biochem, 119, 157-184.

Katoh, H.Watanabe, T.Ohmori, H.Kawamura, K. and Makino, Y. (2005). Carbonization of johkasou sludge using batch-type equipment. J Mater Cycles Waste Manag, 7, 55-64.

Kezelis, R.Mecius, V.Valinciute, V. and Valincius, V. (2004). Waste and Biomass Treatment Employing Plasma Technology. High Technology Plasma Processes, 8, 273-282.

Kim, H. I. and Park, D. W. (2004). Characteristics of fly ash/sludge slags vitrified by thermal plasma. Ind. Eng. Chem, 10(2), 234-238.

Kim, S.Moon, S., H. and Kim, K. W. (2001). Removal of Heavy Metals from Soils using Enhanced Electrokinetic Soil Processing. Water, Air, and Soil Pollution, 125(1), 259-272.

Kimura, T.Takase, K. and Tanaka, S. (2007). Concentration of copper and a copper–EDTA complex at the pH junction formed in soil by an electrokinetic remediation process. Journal of Hazardous Materials, 143(3), 668-672.

Kobya, M.Erdem, N. and Demirbas, E. (2015). Treatment of Cr, Ni and Zn from galvanic rinsing wastewater by electrocoagulation process using iron electrodes. Desalination and Water Treatment, 56(5), 1191-1201.

Kogelschatz, U. (2004). Atmospheric-pressure plasma technology. Plasma Phys. Controlled Fusion, 46, B63–B75.

Kunio, K.Hiroshi, K.Toru, S. and Koichi, S. (1975). Method for incinerating industrial wastage: Google Patents.

Kuo, Y.Chang, J.Chang, K.Chao, C.Tuan, Y. and Chang-Chien, G. (2010). Stabilization of residues obtained from the treatment of laboratory waste. part 1-Treatment path of metals in a plasma melting system. Journal of the Air & Waste Management Association, 60(4), 429-438.

Kwak, T.Lee, S.Maken, S.Shin, H.Park, J. and Yoo, Y. D. (2005). A study of gasification of municipal solid waste using a double inverse diffusion flame burner. Energy & Fuels, 19(6), 2268-2272.

Kwak, T.Lee, S.Park, J.Maken, S.Yoo, Y. D. and Lee, S. (2006a). Gasification of municipal solid waste in a pilot plant and its impact on environment. Korean Journal of Chemical Engineering, 23(6), 954-960.

Kwak, T.Maken, S.Lee, S.Park, J.Min, B. and Yoo, Y. D. (2006b). Environmental aspects of gasification of korean municipal solid waste in a pilot plant. Fuel,, 85(14-15), 2012-2017.

Leal-Quirós, E. (2004). Plasma processing of municipal solid waste. Brazilian J. of Phys., 34(4B), 1587-1593.

Leštan, D.Luo, C. and Li, X. (2008). The use of chelating agents in the remediation of metal-contaminated soils: A review. Environmental Pollution, 153(1), 3-13.

Li, C.-T.Lee, W.-J.Huang, K.-L.Fu, S.-F. and Lai, Y.-C. (2007). Vitrification of Chromium Electroplating Sludge. Environmental Science & Technology,

Li, J.Liu, K.Yan, S.Li, Y. and Han, D. (2016). Application of thermal plasma technology for the treatment of solid wastes in China: An overview. Waste Management, 58, 260-269.

Li, O.Guo, Y.Chang, J.Urashima, K. and Saito, N. (2012). Treatment of non-point sources by a thermal plasma system under a DC partial transferred mode. Int J Plasma Environ Sci Technol, 6(1), 63-67.

Li, O. L.Guo, Y.Chang, J. S. and Saito, N. (2015a). Thermal plasma treatment of stormwater sediments: comparison between DC non-transferred and partially transferred arc plasma. Environmental Technology, 36(13), 1672-1679.

Li, O. L.Guo, Y.Chang, J. S.Urashima, K. and Saito, N. (2015b). A new approach of nonpoint source pollution/stormwater sludge treatment by an integrated thermal plasma system. International Journal of Environmental Science and Technology, 12, 1769 -1778.

Lin, K.-H.Hsu, H.-T.Ko, Y.-W.Shieh, Z.-X. and Chiang, H.-L. (2009). Pyrolytic product characteristics of biosludge from the wastewater treatment plant of a petrochemical industry. Journal of Hazardous Materials, 171(1), 208-214.

Lundstedt, T.Seifert, E.Abramo, L.Thelin, B.Nyström, Å.Pettersen, J. and Bergman, R. (1998). Experimental design and optimization. Chemometrics and intelligent laboratory systems, 42(1), 3-40.

Ma, W.Fang, Y.Chen, D.Chen, G.Xu, Y.Sheng, H. and Zhou, Z. (2017). Volatilization and leaching behavior of heavy metals in MSW incineration fly ash in a DC arc plasma furnace. Fuel, 210, 145-153.

Mahmood, T. and Elliott, A. (2006). A review of secondary sludge reduction technologies for the pulp and paper industry. Water Research, 40(11), 2093-2112.

Malakahmad, A. and Chuan, S. Y. (2013). Application of response surface methodology to optimize coagulation–flocculation treatment of anaerobically digested palm oil mill effluent using alum. Desalination and Water Treatment, 51(34-36), 6729-6735.

Marani, D.Braguglia, C. M.Mininni, G. and Maccioni, F. (2003). Behaviour of Cd, Cr, Mn, Ni, Pb, and Zn in sewage sludge incineration by fluidised bed furnace. Waste Manag, 23, 117-124.

Maria, E. D. B. R. (2011). Cost-benefit analysis of a waste to energy plant for montevideo; and waste to energy in small islands. (MSc), university of columbia, columbia.

Mei, D.He, Y. L.Liu, S.Yan, J. and Tu, X. (2016). Optimization of CO2 Conversion in a Cylindrical Dielectric Barrier Discharge Reactor Using Design of Experiments. Plasma Processes and Polymers, 13(5), 544-556.

Menéndez, J. A.Domínguez, A.Inguanzo, M. and Pis, J. J. (2005). Microwave-induced drying, pyrolysis and gasification (MWDPG) of sewage sludge: Vitrification of the solid residue. Journal of Analytical and Applied Pyrolysis, 74(1–2), 406-412.

Mitrasinovic, A.Pershin, L.Wen, J. Z. and Mostaghimi, J. (2011). Recovery of Cu and valuable metals from E-waste using thermal plasma treatment. J. mater., 63(8), 24-28.

Mohai, I. and Szépvölgyi, J. (2005). Treatment of particulate metallurgical wastes in thermal plasmas. Chemical Engineering and Processing: Process Intensification, 44(2), 225-229.

Mohai, I.Szépvölgyi, J. and Károly, Z. e. a. (2001). Reduction of Metallurgical Wastes in an RF Thermal Plasma Reactor. Plasma Chemistry and Plasma Processing, 21, 547-563.

Mohammadi, T.Razmi, A. and Sadrzadeh, M. (2004). Desalination Strategies in South Mediterranean Countries. Effect of operating parameters on Pb2+ separation from wastewater using electrodialysis. Desalination, 167, 379-385.

Mountouris, A.Voutsas, E. and Tassios, D. (2008). Plasma gasification of sewage sludge: Process development and energy optimization. Energy Conversion and Management, 49(8), 2264-2271.

Moustakas, K.Fatta, D.Malamis, S.Haralambous, K. and Loizidou, M. (2005). Demonstration plasma gasification/vitrification system for effective hazardous waste treatment. Journal of Hazardous Materials B123 (2005) 120–126, B123, 120-126.

Moustakas, K.Papadopoulos, A.Fatta, D.Haralambous, K. J. and Loizidou, M. (2003). Design and construction of a demonstration plasma gasification/vitrification unit for waste treatment. Paper presented at the 8th international conference on environmental science and technology, Lemnos island greece.

Moustakas, K.Xydis, G.Malamis, S.Haralambous, K. J. and Loizidou, M. (2008a). Analysis of results from the operation of a pilot plasma gasification/vitrification unit for optimizing its performance. Journal of Hazardous Materials, 151(2), 473-480.

Moustakas, K.Xydis, G.Malamis, S.Haralambous, K. J. and Loizidou, M. (2008b). Analysis of results from the operation of a pilot plasma gasification/vitrification unit for optimizing its performance. J. of Hazard.Mater. Res, 151, 473-480.

Mukherjee, P. S.Bhoi, B.Mishra, C. R.Dash, R. R.Satapathy, B. K. and Jayasankar, K. (2012). Production of Pig iron from Nalco redmud by application of plasma smelting technology Symposium on Light Metals / TMS Annual Meeting and Exhibition (pp. 99-103).

Murakami, T.Suda, T.Mouri, S.Shigeta, J.Hirata, T.Fujimori, T. and Huang, W. (2006). Co-gasification of Sewage Sludge and Plastic Wastes: Evaluation of Experiment and Application. Journal of the Japan Institute of Energy, 85, 964-970.

Murakami, T.Suzuki, Y.Nagasawa, H.Yamamoto, T.Koseki, T.Hirose, H. and Okamoto, S. (2009). Combustion characteristics of sewage sludge in an incineration plant for energy recovery. Fuel Processing Technology, 90, 778 - 783.

Naoum, C.Fatta, D.Haralambous, K. J. and Loizidou, M. (2001). Removal of heavy metals from sewage sludge by acid treatment. Journal of Environmental Science and Health, Part A, 36(5), 873-881.

Nema, S. and Ganeshprasad, K. (2002a). Plasma pyrolysis of medical waste. Current Science, 83(3), 271-278.

Nema, S. K. and Ganeshprasad, K. S. (2002b). Plasma pyrolysis of medical waste. Current Science, 83(3), 271-278.

Nikolay, M. and Maria, Y. (2017a). Methods and solutions for galvanic waste water treatment. Paper presented at the MATEC Web of Conferences.

Nikolay, M. and Maria, Y. (2017b). Methods and solutions for galvanic waste water treatment. Paper presented at the MATEC Web of Conferences.

Pan, X.Jianhua, Y. and Zhengmiao, X. (2013). Detoxifying PCDD/Fs and heavy metals in fly ash from medical waste incinerators with a DC double arc plasma torch. Journal of Environmental Sciences, 25(7), 1362–1367.

Pan, X. and Xie, Z. (2014). Characteristics of Melting Incinerator Ashes Using a Direct Current Plasma Torch. Environmental and analytical toxicoogy, 4(3).

Park, H. S.Lee, B. J. and Kim, S. J. (2005). Medical waste treatment using plasma. J. Ind. Eng. Chem, 11, 353-360.

Patel, M. L. and Chauhan, J. S. (2012). Plasma Gasification: A Sustainable Solution for the Municipal Solid Waste Management in the State of Madhya Pradesh, India. International Journal of Environmental Sciences, 3(1).

Pérez-Villarejo, L.Martínez-Martínez, S.Carrasco-Hurtado, B.Eliche-Quesada, D.Ureña-Nieto, C. and Sánchez-Soto, P. J. (2015). Valorization and inertization of galvanic sludge waste in clay bricks. Applied Clay Science, 105(Supplement C), 89-99.

Peter, M. (2011). Historical Development of Hot - dip Galvanizing. Handbook of Hot Dip Galvanizing: WILEY-VCH Verlag GmbH & Co.

Poiroux, R. and Rollin, M. (1996). High temperature treatment of waste: from laboratories to the industrial stage. Pure Appl. Chem, 68, 1035-1040.

Pourali, M. (2010). Application of Plasma Gasification Technology in Waste to Energy-Challenges and Opportunities. IEEE Transactions on Sustainable Energy, 1(3), 125 -130.

Raissi, S. (2009). Developing new processes and optimizing performance using response surface methodology. World Academy of Science, Engineering and Technology, 49, 1039-1042.

Ramachandran, K. and Kikukawa, N. (2000). Plasma in-flight treatment of electroplating sludge. Vacuum, 59, 244-251.

Ramachandran, K. and Kikukawa, N. (2002). Thermal plasma in-flight treatment of electroplating sludge. IEEE Trans. Plasma Sci, 30, 310-317.

Rao, L.Carabin, P. and Holcroft, G. (2010, 5-8 October, 2010). Plasma Waste Gasification: Decentralized Approach to Production of Energy From Waste. Paper presented at the 2nd International Conference on Hazardous and Industrial Waste Management, Chania, Crete, Greece.

Rashid, K.Sinha, K. and P.C., S. (2013). An update on oxidative stress-mediated organ pathophysiology. Food Chem Toxicol, 62, 584-600.

Rath, S. S.Jayasankar, K.Satapathy, B. K.Mishra, B. K. and Mukherjee, P. S. (2011). Kinetics and statistical behaviour of iron recovery from red mud using plasma arc furnace. High Temp. Mater. Process, 30(3), 211.

Rath, S. S.Pany, A.Jayasankar, K.Mitra, A. K.Kumar, C. S. and Mukjerjee, P. S. (2013). Statistical modeling studies of iron recovery from red mud using thermal plasma. Plasma Sci. Technol, 15(5), 459-464.

Reddy, K. R. and Chinthamreddy, S. (1999). Electrokinetic remediation of heavy metal-contaminated soils under reducing environments. Waste Management, 19(4), 269-282.

Rodrigues, R. C.Kenealy, W. R.Dietrich, D. and Jeffries, T. W. (2012). Response surface methodology (RSM) to evaluate moisture effects on corn stover in recovering xylose by DEO hydrolysis. Bioresour Technol, 108, 134-139.

Rossini, G. and Bernardes, A. M. (2006). Galvanic sludge metals recovery by pyrometallurgical and hydrometallurgical treatment. Journal of Hazardous Materials, 131(1–3), 210-216.

Rousseau, C.Baraud, F.Leleyter, L. and Gil, O. (2009). Cathodic protection by zinc sacrificial anodes: Impact on marine sediment metallic contamination. Journal of Hazardous Materials, 167(1), 953-958.

Ruj, B. and Ghosh, S. (2014). Technological aspects for thermal plasma treatment of municipal solid waste—A review. Fuel Processing Technology, 126, 298-308.

Rutberg, P. G.Bratsev, A. N.Safronov, A. A.Surov, A. V. and Schegolev, V. V. (2002). The technology and execution of plasmachemical disinfection of hazardous medical waste. IEEE TRANSACTIONS ON PLASMA SCIENCE, 30(4), 1445-1448. doi: 10.1109/TPS.2002.804218

Saffarzadeh, A.Shimaoka, T.Motomura, Y. and Watanabe, K. (2006). Chemical and mineralogical evaluation of slag products derived from the pyrolysis/melting treatment of MSW. Waste Management, 26(12), 1443-1452.

Saffarzadeh, A.Shimaoka, T.Motomura, Y. and Watanabe, K. (2009). Characterization study of heavy metal-bearing phases in MSW slag. Journal of Hazardous Materials, 164(2-3), 829-834.

Saher, S. and Abdel Hamid, Z. (2003). Effect of aluminium content on the coating structure and dross formation in the hot-dip galvanizing process. Surface and Interface Analysis. Wiley InterScience (www.interscience.wiley.com), 35, 934-947.

Salem, H. M.Eweida, E. A. and Farag, A. (2000). Heavy metals in drinking water & their environment impact on human health. . Paper presented at the International Conference for Environmental Hazards Mitigation. ICEHM, Cairo University,Giza, Egypt.

Samal, S. (2017). Thermal plasma technology: The prospective future in material processing. Journal of Cleaner Production, 142(Part 4), 3131-3150.

Samal, S. K.Sindhoora, L. P.Mishra, S. C. and Mishra, B. (2015). Studies on plasma processing of blue dust. Paper presented at the 4th National Conference on Processing and Characterization of Materials. IOP Conf. Series. Materials Science and Engineering.

Sankarammal, M.Thatheyus, A. and Ramya, D. (2014). Bioremoval of cadmium using pseudomonas fluorescens. Open J. Water Pollut. Treat(1), 92-100.

Santanu, P. and Pak, K. Y. (2006). Solidification–stabilization of organic and inorganic contaminants using portland cement: a literature review. Environ. Rev., 14.

Schulz, W. D. and Thiele, M. (Eds.). (2011). Hot dip Galvanizing and Layer formation Technology. Hand book on hot dip galvanising.: Wiley-VCH Verlag GmbH.

Sebag, M. G.Korzenowski, C.Bernardes, A. M. and Vilela, A. C. (2009). Evaluation of environmental compatibility of EAFD using different leaching standards. Journal of Hazardous Materials, 166(2), 670-675.

Seo, J.-H. and Hong, B.-G. (2012). Thermal plasma synthesis of nano-sized powders. Nuclear engineering and technology, 44(1), 9-20.

Shen, L. and Zhang, D. (2005). Low-temperature pyrolysis of sewage sludge and putrescible garbage for fuel oil production. Fuel, 84(7–8), 809-815.

Shie, J.Yi-Ru, L.Kae-Long, L. and Ching-Yuan, C. (2014a). Thermal Treatment of Paper Sludge Using Torch Plasma. Paper presented at the 4th International Conference on Future Environment and Energy.IPCBEE, Singapore

Shie, J. L.Liau, Y. R.Lin, K. L. and Chang, C. Y. (2014b). Thermal Treatment of Paper Sludge Using Torch Plasma. Paper presented at the 4th International Conference on Future Environment and Energy, Singapore.

Shin, H. S. and Jun, K. S. (1995). Cement based stabilization/solidification of organic contaminated hazardous wastes using Na-bentonite and silica-fume. Journal of Environmental Science and Health . Part A: Environmental Science and Engineering and Toxicology, 30(3), 651-668.

Shiro, Y. and Tahei, T. (2000). Principle and Process of Heavy Metal Removal from Sewage Sludge. Environ Sci Technol, 34, 1572-1575.

Smith, W. J. and Goodwin, F. E. (2010). Hot Dip Coatings. Retrieved from

Sobiecka, E. and Szymanski, L. (2014). Thermal plasma vitrification process as an effective technology for fly ash and chromium-rich sewage sludge utilization. Journal of Chemical Technology and Biotechnology, 89(7), 1115-1117.

Stoica, A.Sandberg, M. and Holby, O. (2009). Energy Use and Recovery Strategies within Wastewater Treatment and Sludge Handling at Pulp and Paper Mills. Bioresour Technol, 100(14), 3497-3505.

Stylianou, M. A.Kollia, D.Haralambous, K.-J.Inglezakis, V. J.Moustakas, K. G. and Loizidou, M. D. (2007). Effect of acid treatment on the removal of heavy metals from sewage sludge. Desalination, 215(1), 73-81.

Sullivan, C.Tyrer, M.Cheeseman, C. R. and Graham, N. J. D. (2010). Disposal of water treatment wastes containing arsenic. Sci. Total Environ, 408, 1770-1778.

Szente, R. N.Bender, O. W.Schroeter, R. A.Gracia, M. G. and Barbosa, L. (1998). Treating Electroplating Residues by Plasma-Lab and Pilot Scale Tests., (CEP 05508-901)Cidade Universitaria, Sao Paulo, Brazil.

Tandero, C.Tixier, C.Trisant, P.Desmaison, J. and Leprince, P. (2006). Atomospheric pressure plasma: A Review. spectrochimica Acta Part B. Atomic spectroscopy, 61(1), 2-30.

Tang, L. and Huang, H. (2005). Treatment of Waste Tyre Powder Using a High-frequency Capacitively Coupled Plasma Reactor. The Chinese Journal of Process Engineering, 5(3).

Tang, L.Huang, H.Zhao, Z. L.Wu, C. Z. and Chen, Y. (2003). Pyrolysis of polypropylene in a nitrogen plasma reactor. Ind Eng Chem Res, 42(6), 1145-1150.

Tanigaki, N.Manako, K. and Osada, M. (2012). Co-gasification of municipal solid waste and material recovery in a large-scale gasification and melting system. Waste Management, 32(4), 667-675.

Tchounwou, P. B.Yedjou, C. G.Patlolla, A. K. and Sutton, D. J. (2012). Heavy Metal Toxicity and the Environment. In Luch, A. (Ed.), Molecular, Clinical and Environmental Toxicology: Volume 3: Environmental Toxicology (pp. 133-164). Basel: Springer Basel.

Tian, M.Park, H. and Row, K. H. (2014). Optimization of Synthesis Amounts of Polymers with Two Monomers by Different Methods Based on Response Surface Methodology. Advances in Polymer Technology, 33(2).

Tippayawong, N. and Khongkrapan, P. (2009). Development of a laboratory scale air plasma torch and its application to electronic waste treatment. Int. J. Environ. Sci. Tech., 6(3), 407-414.

Toledo, J. M.Corella, J. and Corella, L. M. (2005). The partitioning of heavy metals in incineration of sludges and waste in a bubbling fluidized bed: 2. Interpretation of results with a conceptual model. J Hazard Mater, 126(1–3), 158-168.

Toropov, V. V.van Keulen, F.Markine, V. and De Doer, H. (1996). Refinements in the multi-point approximation method to reduce the effects of noisy structural responses. Paper presented at the Proceedings 6th AIAA/USAF/NASA/ ISSMO symposium on multidisciplinary analysis and optimization.

Tuan, Y. J.Wang, H. P. and Chang, J. E. (2012). Tracking of chromium in plasma co-melting of fly ashes and sludges. Water, Air, & Soil Pollution, 223(8), 5283-5288.

Tzeng, C., C.Kuo, Y. Y.Huang, T. F.Lin, D. L. and Yu, Y. J. (1998). Treatment of radioactive wastes by plasma incineration and vitrification for final disposal. Journal of Hazardous Materials, 58(1), 207-220.

Van Oost, G.HrabovskyKopecky, M. V.Konrad, M.Hlina, M. and Kavka, T. (2009). Pyrolysis/gasification of biomass for synthetic fuel production using a hybrid gas-water stabilized plasma torch. Vacuum, 83, 209-212.

Wang, J.Feng, X.Anderson, C. W. N.Xing, Y. and Shang, L. (2012). Remediation of mercury contaminated sites – A review. Journal of Hazardous Materials, 221-222, 1-18.

Wang, Q.Yan, J. H.Tu.X.Chi, Y.Li, X. D. and Lu, S. Y. (2009). Thermal treatment of municipal solid waste incinerator fly ash using DC double arc argon plasma. Fuel, 88(5), 955-958.

Wang, S. B.Cheng, C. M.Lan, W.Zhang, X. H.Liu, D. P. and Yang, S. Z. (2013). Experimental Study of Thermal Plasma Processing Waste Circuit Boards. Advanced Materials Research, 652-654, 1553-1561.

Wang, Z.Guo, Q.Liu, X. and Cao, C. (2007). Low Temperature Pyrolysis Characteristics of Oil Sludge under Various Heating Conditions. Energy & Fuels, 21, 957-962.

watanabe, N. T. (2013). Decomposition of Glycerine by Water Plasmas at Atmospheric Pressure. Plasma Science and Technology, 15(4), 1-6.

Watanabe, T. and Shimbara, S. (2003). Halogenated hydrocarbon decomposition by steam thermal plasmas. High Temp. Mater. Process, 7, 455-474.

Weia, Y. L. and Wua, C. H. (1997). PAH Emissions from the Fluidized-Bed Incineration of an Industrial Sludge. Journal of the Air & Waste Management Association, 47(9), 953-960.

Werle, S. (2015a). Gasification of a Dried Sewage Sludge in a Laboratory Scale Fixed Bed Reactor. Energies, 8, 8562-8572.

Werle, S. (2015b). Nitrogen Oxides Emission Reduction Using Sewage Sludge Gasification Gas Reburning Process. Ecol Chem Eng S., 22(1), 83-94.

Westinghouse-plasma. (2015). Retrieved 23 october, 2015, from http://www.westinghouse-plasma.com.

Yeung, A. T.Hsu, C. N. and Menon , R. M. (1996). EDTA-enhanced electrokinetic extraction of lead. J Geotech Eng, 122(8), 666-673.

Yi-Ming, K.Kuo-Lin, H. and Chitsan, L. (2012). Metal Behavior during Vitrification of Municipal Solid Waste Incinerator Fly Ash. Aerosol and Air Quality Research, 12, 1379-1385.

Zaidon, A. K.Paridah, G. H.Bakar, M. T. and Rushdan, I. (2012). Optimisation of The Processing Variables for High Polymer Loading in Compressed Wood Using Response Surface Methodology. Journal of Tropical Forest Science, 24(2), 241-248.

Zhang, Q. (2011). Mathematical modeling of municipal solid waste plasma gasification in a fixed-bed melting reactor. (Doctoral Dissertation), SE-100 44 Stockholm, Sweden.

Zhang, Q.Dor, L.Fenigshtein, D.Yang, W. and Blasiak, W. (2012). Gasification of municipal solid waste in the plasma gasification melting process. Appl. Energ, 90, 106-112.

Zhen, H.Xu-tao, Z. and Gui-qing, X. (2013). Product Quality Improvement Through Response Surface Methodology: A Case Study. . Paper presented at the International Conference on Technology Innovation and Industrial Management.

Zlebek, Z.Hodul, J. and Drochytka, R. (2018). Repairing composite using hazardous waste containing heavy metals. IOP Conference Series: Materials Science and Engineering, 385(385), 1-6.