HEAVY METAL REMOVAL FROM SEMICONDUCTOR INDUSTRY WASTEWATER A REVIEW ON ION EXCHANGE PROCESS USING RESIN

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SCHOOL OF CIVIL ENGINEERING
UNIVERSITI SAINS MALAYSIA
2021

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by

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This dissertation is submitted to

UNIVERSITI SAINS MALAYSIA

As partial fulfilment of requirement for the degree of

BACHELOR OF ENGINEERING (HONS.)
(CIVIL ENGINEERING)

School of Civil Engineering
Universiti Sains Malaysia

August 2021

Appendix A8

UNIVERSITI SAINS MALAYSIA

SCHOOL OF CIVIL ENGINEERING
ACADEMIC SESSION 2020/2021

FINAL YEAR PROJECT EAA492/6
DISSERTATION ENDORSEMENT FORM

Title: Heavy Metal Removal From Semiconductor Industry Wastewater A Review On Ion Exchange Process Using Resin

Name of Student: Nurul Arisya Shuhada Binti Sabri

I hereby declare that all corrections and comments made by the supervisor(s)and examiner have been taken into consideration and rectified accordingly.

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Date: 6/08/2021

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(Signature of Examiner)

Name of Examiner: Dr Rosnani Alkarimiah

Date: 6/08/2021

ACKNOWLEDGEMENT

Alhamdulillah, in the name of God, the Beneficent, the Merciful. I would like to thank Universiti Sains Malaysia for giving me the opportunity to conduct this research as my final year project. After all of the hard effort being put into this year, I feel compelled to express my appreciation to everyone who has contributed and supported me in any way in order for me to complete my study. I would like to express my greatest gratitude to my beloved supervisor, Assoc. Prof. Dr. Puganeshwary A/P Palaniandy for her help, supports, guidance and enormous patience through my journey in finishing of this thesis. As well as Assoc. Prof. Dr. Noor Faizah Fitri Md. Yusof, Dr Noorhazlinda Abd Rahman, and Dr Nik Azimatolakma Awang for help and motivations. My deepest appreciation to my parents, Sabri Shafie and Rosliza Din and family for endlessly support through my ups and down in study time, making me feel loved and blessed. You are my light at the end of the dark tunnel.

Special thanks to USM Library team Mdm. Jamilah Hassan Basri and Mdm Mazainun Aini Mod zain who had given the full commitment, patience in in giving knowledge and guidance on thesis template as well as database and endnote. Not to forget, thank you to all my friends especially Shazarul and Shaneez whom I had referred with. My roommate, Shafiqa and Musliha and lastly to my senior Falikh. Thanks for the advice, knowledge shared and support.

Finally, I cannot be more thankful to everyone who has directly or indirectly giving me motivation, encouragement, and moral support.

ABSTRAK

Kekurangan bekalan air bawah tanah yang disebabkan oleh penurunan kualiti permukaan air merupakan semakin yang penting. Banyak syarikat perkilangan di negara perindustrian seperti Malaysia melepaskan limbahnya ke dalam badan air yang perlu dirawat telah meningkatkan permintaan untuk rawatan air sisa. Resin pertukaran ion adalah salah satu cara yang paling berjaya untuk membuang ion logam berat dari air sisa industri semikonduktor, dan mungkin digunakan semula berkali-kali. Tujuan kajian ini adalah untuk menggunakan resin pertukaran ion sebagai penyerap untuk menghilangkan logam berat yang lazim terdapat dalam efluen industri semikonduktor. Hasil kajian literatur sistematik terhadap tiga puluh makalah menunjukkan parameter yang paling biasa untuk disiasat adalah kesan masa hubungan antara 80 hingga 360 minit, kepekatan awal berkisar antara 0.2-3g dan dos resin antara 0.1-2.0 g. pH air buangan pada 5 sudah mencapai julat keseimbangan 83% hingga 97% menurut kajian. Resin yang jauh lebih biasa digunakan untuk mengeluarkan logam berat dari efluen semikonduktor dan larutan berair juga dibandingkan dan dibezakan. Kecuali untuk Lewatit CNP80 yang mempunyai kumpulan karboksilik sementara D401 dan 732-Cr mempunyai penukar kapasiti total yang tinggi dan kumpulan berfungsi yang sama dengan asid sulfonat. Kinetik pertukaran ion sering merupakan kinetika urutan pertama pseudo dan kinetik urutan kedua pseudo, di mana data yang diperoleh menunjukkan pekali korelasi kurang dari satu untuk kedua kinetik pertukaran ion. Manakala isoterm pertukaran ion sering didasarkan pada dua isoterm utama, model Langmuir dan Freundlich dengan pekali regresi R^2 tertinggi.

ABSTRACT

Due to a scarcity of surface water supply caused by declining water surface quality, groundwater is becoming an increasingly essential source of water. Many manufacturing firms in an industrialized country like Malaysia release their effluent into bodies of water that must be treated, increasing the demand for wastewater treatment. Ion exchange resin is one of the most successful ways for removing heavy metal ions from semiconductor industry wastewater, and it may be reused numerous times. The goal of this study was to use ion exchange resin as an adsorbent to remove typical heavy metals prevalent in semiconductor industry effluent. The results of a systematic literature study of thirty papers show the most common parameters to investigate are the effects of contact times ranging from 80 to 360 minutes, initial concentrations ranging from 0.2-3.0 g and resin doses ranging from 0.1-3.0 g. The pH of wastewater at 5 has already reached the equilibrium range of 83% to 97% according to the study. The far more typically used resins for removing heavy metals from semiconductor effluent and aqueous solutions are also compared and differentiated. Except for Lewatit CNP80 which has a carboxylic group while D401 and 732-Cr have high total capacity exchangers and the same functional group as sulphonic acid. Ion exchange kinetics are frequently pseudo first-order and pseudo second-order kinetics, where the data obtained indicates a correlation coefficient less than one for both ion exchange kinetics. Whereas ion exchange isotherms are frequently based on two primary isotherms, the Langmuir and Freundlich models with the highest R^2 regression coefficient.

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LIST OF ABBREVIATIONS

DOE	Department of Environment
EQR	Environmental Quality Regulations
IER	Ion exchange resin
k_2	Pseudo first order rate constant
k_1	Pseudo first order rate constant
Na X	Nano zeolite
PGMs	Platinum group metals
ppb	Part per billion
ppm	Part per million
R^2	Regression coefficient
SLR	Systematic literature review
TU	Toxic unit
WAC	Weak acid cation
WHO	World Health Organization
732 CR	732 cation resin

CHAPTER 1

INTRODUCTION

1.1 Background

Water is the necessity for all living beings for our survival and to execute domestic household activities or industrial process (Malik et al., 2020). Due to rapid industrialization and urbanization, these activities have led to environments issues especially polluted water where the discharge from industries contains various pollutants such as heavy metals that can diminished our water resources. Heavy metals contaminated wastewater into water bodies originates from anthropogenic activities in various sector, for instance agricultural activities, mining, electronic device manufacturing, electroplating, metal processing and power generation facilities (Chai et al., 2021). Polluted water source not only incurred high cost of treatment however it also lessens the capability of water supply demand.

Heavy metals generally known as group of metals and metalloids that have relatively high atomic weight or high density and toxic at parts per billion (ppb) levels (Yadav et al., 2019). Besides, heavy metals with an atomic density higher than 4 ± 1 g/cm^3 (Chai et al., 2021) are classified as nonbiodegradable pollutants, toxic and have high tendency to accumulate in environmental and living beings at low concentrations (Al-Saydeh et al., 2017). Some of metalloids and lighter metals name as selenium, arsenic and aluminium are toxic while heavy metals such as gold element is non-toxic. The list of heavy metals with density being greater than 5 g/cm^3 are titanium, vanadium, chromium, manganese, iron, cobalt, nickel, copper, zinc, molybdenum, silver, cadmium, tin, platinum, gold, mercury and lead (Briffa et al., 2020).

A semiconductor is a silicon-based substance that conducts electricity more than an insulator, such as glass, but less than a pure conductor, such as copper or aluminium. Displays, autonomous vehicles, smart factories, artificial intelligence, robotics and the connected life are all depend on semiconductors which are irreplaceable in the area of new (Kim et al., 2021). In semiconductor manufacturing, it is one of the largest industries for water use, since the manufacture of semi-conductor wafers uses an enormity of water during the cleaning and rinsing process. A highly complicated operation, hundreds of which are repeated procedures, fast technical advancement, high confidentiality and huge investments promote innovation and mass manufacturing and vast chemical use is the feature of the semiconductor industry (Yoon et al., 2020). The most common heavy metals found in contaminated semiconductor industrial wastewater are cadmium, zinc, lead, nickel and copper which found to be toxic, carcinogenic and causes a serious threat to the ecosystem if it is discharged into the waterbody (Gunatilake, 2015). Owing to such conditions, it is important to eliminate the heavy metal from the wastewater before the treated wastewater reached the water body. Wastewater regulations were established to minimize human and environmental exposure to hazardous chemicals. These include limits on the types and concentration of heavy metals that may be present in the discharge treated wastewater.

In order to maintain the quality of the water, several techniques have been developed to purify industrial effluents before being discharges to the main streams. Several heavy metal removal methods have been developed and thoroughly researched over the past few decades. Heavy metal removal techniques include chemical precipitation, adsorption, ion exchange, membrane filtration, coagulation-flocculation, and floatation (Tahir et al., 2017). Due to their many benefits, such as high treatment capability, high removal performance, and quick kinetics, ion exchange processes have been commonly used to eliminate heavy metals from wastewater. Synthetic or natural solid ion exchange resin has the unique capacity to exchange the cations with metals in wastewater. Synthetic resins are widely favoured among the materials used in ion-exchange processes because they are successful in approximately removing the heavy from the solution (Tahir et al., 2017). Certain variables such as PH, temperature, initial metal concentration, and contact time have a significant impact on the uptake of heavy metal ions by ion-exchange resins (Tahir et al., 2017). In this study, the effectiveness of ion exchange process using resin as an adsorbent in removal of heavy metals will be review.

In industrial wastewater treatment, resin mainly used to recover heavy metals and precious metals and to purify toxic substances (Mohy Eldin et al., 2016). The removal of heavy metals by ion exchange processes with different natural or synthesized resins is one of the most promising approaches due to its effectiveness and properties of easily recovered end-products, as well as the likelihood of reuse following regeneration processes. The ion exchange resin (IER) is a synthetic functional polymer material that contains a reactive group which obtained by introducing a crosslinked polymer copolymer into ion exchange groups of different properties (Mohy Eldin et al., 2016). Ion exchange resin consists of cation exchange resins for positively charged ions and anion exchange resins for negatively charged ions. In adsorption resin use as adsorbent trough ion exchange method that are significant processes in wastewater treatment. When semiconductor wastewater comes into contact with suspended matter or heavy metals, a substantial number of contaminants may be transferred by adsorption and anion ion exchange resin, and the impurities absorbed by the resin may not be conveyed by clear water. The use of resin as an adsorbent in the removal of heavy metals is effective, and synthetic resins are chosen because they can nearly eliminate heavy metals from a solution. (Arbabi and Golshani, 2016).

1.2 Review Questions

In this review topic, there are six different review question have been constructed as listed below:

RQ1. What are heavy metals and what are the most common heavy metals found in semiconductor industrial wastewater and the causes of their existence?

RQ2. How ion exchange process going to remove heavy metals from semiconductor industrial wastewater?

RQ3. Why ion resin is being used as an adsorbent?

RQ4. How resin can be used as an adsorbent to remove heavy metals from semiconductor industrial wastewater by ion exchange process?

1.3 Objectives of the Systematic Review

The core purposes of this research are to review on a measure of treatability of semiconductor industrial wastewater in order to remove certain heavy metals that have contaminated the wastewater as well as to study the capability of adsorbent namely resin to adsorb the heavy metals. Subsequently, this review objectives are highly related to review question as following:

RO1. To identify the type and concentration of heavy metal in semiconductor industrial wastewater.

RO2. To study the application and capability of ion exchange process in heavy metal removal in semiconductor industrial wastewater.

RO3. To study the resin characteristics and properties to be used as an adsorbent in heavy metal removal.

RO4. To identify the mechanism involved that makes ion exchange process feasible to be used in heavy metal removal.

1.4 Scope of the Systematic Review

The review questions and review objectives that have been produced from the review topic determine the scope of this investigation. The major goal is to assess resin's ability to remove heavy metals from semiconductor manufacturing wastewater. The concentration value evaluated from earlier studies, which showed the most prevalent type of heavy metals found in semiconductor wastewater, is one factor that determines the selection of these heavy metals. The systematic literature review (SLR) approach is used to evaluate research papers, research articles, journals, book chapters, and books that are closely related to the review questions and objectives.

1.5 Significance of the Systematic Review

The research is important in order to identify and comprehend the types of heavy metals contaminated semiconductor industry wastewater, as well as the potential of resin in ion exchange process.

The first chapter contains a brief introduction to the review, the review question, review aims, systematic review scope, and systematic review importance. The systematic literature review (SLR) protocol, which includes planning, conducting, and reporting the SLR, is described in Chapter 2. The third chapter is an SLR methodology that lists all of the data extraction and data analysis/synthesis that were extracted from journals, research articles, research papers, book chapters, and books that were chosen for qualitative synthesis. The fourth chapter is dedicated to the literature review, with a focus on the findings and discussion. This chapter covers the characteristics of review studies as well as a discussion of review questions. The conclusions and recommendations in Chapter 5 are based on the findings and discussion of the review questions.

CHAPTER 2

SYSTEMATIC LITERATURE REVIEW (SLR): A METHODOLOGY

2.1 Introduction

This chapter describes the methods for removing heavy metals from semiconductor manufacturing effluent using resin in an ion exchange process. Furthermore, the research strategy is laid out in such a way that it addresses the thesis's review questions. This SLR methodology is divided into four primary phases based on the four objectives. The four major phases of this investigation are depicted in Table 2.1.

Table 2. 1 Four main phases in SLR study

Phase	**Scope**
First	Identify the type of heavy metal and its concentration in semiconductor wastewater.
Second	Identify the application of ion exchange that has been used to remove heavy metal and analyse its capability by identify its removal.
Third	Identify the resin characteristics and its properties that makes it preferable to be used in ion exchange.
Fourth	Identify the mechanism that involved which makes ion exchange process feasible to be used in heavy metal removal.

2.2 Planning of SLR

The study's most important goal was to investigate the ion exchange process for removing heavy metals from semiconductor manufacturing effluent utilizing resin. Designing and conducting a comprehensive, objective, and systematic literature review is one such goal that will be covered in this study. The systematic review is a well-defined and study-based approach to identifying, analysing, and providing data on a specific innovation's most recent advancements and key components to explain its growth, as well as reviewing information on ongoing research and context and situations to obtain more background details on the science and challenges it faces. (BA & Charters, 2007).

This section defines the SLR analysis technique, which is then used to describe the available literature on the review of ion exchange processes utilizing resin for removing heavy metals from semiconductor manufacturing effluent.

2.2.1 Review protocol

Protocolization is a critical step in conducting a systematic literature review as shown in Figure 2.1. The protocol outlines all the methods and techniques that researchers utilized to eliminate author bias and limit the likelihood of validity during the study. The research process is one of the primary differences between SLR and traditional literature reviews. An independent researcher has examined the protocol used in this study.

Figure 2.1 SLR protocol

The protocol's initial step is to identify the review question, which may entail completing an inquiry, and then fine-tuning the search method and definitions, if necessary. The main research must then be organized in a systematic way to allow for both inclusion and exclusion in the specification. Once study concerns have been discovered from data pieces collected from primary studies, they can be used as instruments to aid in the analysis of the extracted data. When gathering qualitative data, the qualitative approach is used to further filter and synthesize information and findings in order to reduce the danger of drawing inaccurate conclusions.

2.2.2 Formulation of review questions

Researchers and anyone who want to use the study for their own purposes can discover answers in a clearer way. As a result, SLR thinks about the following review question in more depth:

RQ1. What are heavy metals and what are the most common heavy metals found in semiconductor industrial wastewater and the causes of their existence?

RQ2. How ion exchange process going to remove heavy metals from semiconductor industrial wastewater?

RQ3. Why resin ion is being used as an adsorbent?

RQ4. How resin can be used as an adsorbent to remove heavy metals from semiconductor industrial wastewater by ion exchange process?

A systematic review is based on a single review topic and pre-determined review priorities. Doing some scoping searches in a database to see whether the subject has been discussed before and if it is novel is a smart idea. The review questions can then be created from there.

2.3 Conducting SLR

This section includes searching tactics, data extraction, and data synthesis, as well as keywords for finding research publications connected to this topic.

2.3.1 Systematic searching strategies

This procedure was made up of two different ways, which were searching and dissemination. The search approach tries to come up with a good search string and then extracts databases that are relevant. Identification, screening, and distribution are three sub-processes of systematic searching procedures.

The first subprocess is identification, which entails checking for synonyms, comparable names, and keyword variants. It aspires to have additional search options for finding more relevant research papers in the chosen database. The methodology starts with a keyword list that contains keywords from an online thesaurus, keywords from previous studies, Scopus's recommended keywords, and keywords that researchers prefer.

Advanced search strategies based on main and enriched keywords, such as the Boolean operator, search terms, truncation, wildcard, and field code functions, were used in the search, or these search techniques were combined in a full search string. The search phrases are 'copied' into the preferred databases, Scopus' leading database and Science Direct's supporting database, to discover related articles. The corresponding blogger has the option of using manual search methods such as hand-picking and e-mailing.

Table 2.2 Enriching the main keywords for review objectives and review questions

Section	Main Keywords	Enriched Keywords
RO1 To identify the type and concentration of heavy metal in semiconductor industrial wastewater.	Heavy metals Concentration Semiconductor industrial Wastewater	Contamination, pollutant Adsorption Semiconductor manufacturing Effluent, sewerage, waste
RO2 To study the application and capability of ion exchange process in heavy metal removal in semiconductor industrial wastewater.	Application Capability Ion exchange Process	Function, operation Effectiveness, potential, efficiency Cation exchangers, anion exchangers Mechanism, technique, measure
	Heavy metals Removal Semiconductor industrial Wastewater	Contamination, pollutant Discharge, elimination, eradication Semiconductor manufacturing Effluent, sewerage, waste
RO3 To study the resin properties to be used as an adsorbent in heavy metal removal.	Resin properties Adsorbent Heavy metals Removal	Isotherms - Contamination, pollutant Discharge, elimination, eradication
RO4 To identify the mechanism involved that makes ion exchange process feasible to be used in heavy metal removal.	Mechanism Heavy metals Involved Wastewater Ion exchange Process	Process, technique, measure Contamination, pollutant Take place Effluent, sewerage, waste Cation exchangers, anion exchangers Mechanism, technique, measure
RQ1 What are heavy metals and what are the most common	Heavy metals Common Found Semiconductor industrial	Contamination, pollutant Frequent Detected, observed Semiconductor manufacturing

heavy metals found in semiconductor industrial wastewater and the causes of their existence?	Wastewater Causes Existence	Effluent, sewerage, waste Reasons Presence
RQ2 How ion exchange process going to remove heavy metals from semiconductor industrial wastewater?	Ion exchange Heavy metals Mechanism Semiconductor industrial Wastewater	Cation exchangers, anion exchangers Contamination, pollutant Process, technique, measure Semiconductor manufacturing Effluent, sewerage, waste

RQ3 Why resin ion is being used as an adsorbent?	Resin ion Application Mechanism Adsorbent	Ion exchange resin, anion resin, cation resin Function, operation Process, technique, measure -
RQ4 How resin can be used as an adsorbent to remove heavy metals from semiconductor industrial wastewater by ion exchange process?	Resin Adsorbent Removal Semiconductor Industrial Wastewater Ion exchange Process	Chemical materials, synthetic, vicious substance - Discharge, elimination, eradication Semiconductor manufacturing Effluent, sewerage, waste Cation exchangers, anion exchangers Mechanism, technique, measure

Table 2. 3 Full search string for the review objective 1

Database	Search String
Scopus	TITLE-ABS-KEY (("heavy metals" OR "contamination" OR "pollutant") AND ("concentration" OR "adsorption") AND ("semiconductor industrial" OR "semiconductor manufacturing") AND ("wastewater" OR "effluent" OR "sewerage" OR "waste"))
Science Direct	("heavy metals" OR "pollutant") AND ("concentration") AND ("semiconductor industrial" OR "semiconductor manufacturing")

	AND ("wastewater" OR "effluent")
Google Scholar	(("heavy metals" OR "contamination" OR "pollutant") AND ("concentration" OR "adsorption") AND ("semiconductor industrial" OR "semiconductor manufacturing") AND ("wastewater" OR "effluent" OR "sewerage" OR "waste"))

Table 2. 4 Full search string for the review objective 2

Database	Search String
Scopus	TITLE-ABS-KEY (("application" OR "function" OR "operation") AND ("capability" OR "effectiveness" OR "potential" OR "efficiency") AND ("ion exchange" OR "cation exchangers" OR "anion exchangers") AND ("process" OR "mechanism" OR "technique" OR "measure") AND ("heavy metals" OR "contamination" OR "pollutant") AND ("removal" OR "discharge" OR "elimination") AND ("semiconductor industrial" OR "semiconductor manufacturing") AND ("wastewater" OR "effluent" OR "sewerage" OR "waste"))
Science Direct	("application") AND ("capability") AND ("ion exchange") AND ("process) AND ("heavy metals") AND ("removal") AND ("semiconductor industrial") AND ("wastewater")
Google Scholar	(("application" OR "function" OR "operation") AND ("capability" OR "effectiveness" OR "potential" OR "efficiency") AND ("ion exchange" OR "cation exchangers" OR "anion exchangers") AND ("process" OR "mechanism" OR "technique" OR "measure") AND ("heavy metals" OR "contamination" OR "pollutant") AND ("removal" OR "discharge" OR "elimination") AND ("semiconductor industrial" OR "semiconductor manufacturing") AND ("wastewater" OR "effluent" OR "sewerage" OR "waste"))

Table 2. 5 Full search string for the review objective 3

Database	Search String
Scopus	TITLE-ABS-KEY (("resin properties" OR "isotherms") AND ("adsorbent) AND ("heavy metals" OR "contamination" OR "pollutant") AND ("removal" OR "discharge" OR "elimination" OR "eradication"))
Science Direct	("resin properties" OR "chemical treatment") AND ("adsorbent" OR "nanoparticles") AND ("heavy metals" OR "contamination") AND ("removal" OR "discharge"))
Google Scholar	(("resin properties" OR "chemical treatment" OR "mechanical properties") AND ("adsorbent") AND ("heavy metals" OR "contamination" OR "pollutant") AND ("removal" OR "discharge" OR "elimination" OR "eradication"))

Table 2. 6 Full search string for the review objective 4

Database	Search String
Scopus	TITLE-ABS-KEY (("mechanism" OR "process" OR "technique" OR "measure") AND ("heavy metals" OR "contamination" OR "pollutant") AND ("involved" OR "take place") AND ("wastewater" OR "effluent" OR "sewerage" OR "waste") AND ("ion exchange" OR "cation exchangers" OR "anion exchangers") AND ("process" OR "mechanism" OR "technique" OR "measure"))
Science Direct	("resin application" OR "pollutant removal") AND ("heavy metals") AND ("semiconductor industrial") AND ("wastewater") AND ("ion exchange" OR "cation exchangers" OR "anion exchangers") AND ("process")
Google Scholar	(("resin application" OR "treatment" OR "ion exchange" OR "pollutant removal") AND ("heavy metals" OR "contamination" OR "pollutant") AND ("semiconductor industrial" OR "semiconductor manufacturing") AND ("wastewater" OR "effluent" OR "sewerage" OR "waste") AND ("ion exchange" OR "cation exchangers" OR "anion exchangers") AND ("process" OR "mechanism" OR "technique" OR "measure"))

Table 2. 7 Full search string for the review question 1

Database	Search String
Scopus	TITLE-ABS-KEY (("heavy metals" OR "contamination" OR "pollutant") AND ("common heavy metals" OR "frequent heavy metals") AND ("found" OR "detected OR observed") AND ("semiconductor industrial" OR "semiconductor manufacturing") AND ("wastewater" OR "effluent" OR "sewerage" OR "waste") AND ("causes" OR "reasons") AND ("existence" OR "presence"))
Science Direct	("heavy metals" OR "contamination") AND ("concentration" OR "adsorption) AND ("semiconductor industrial" OR "semiconductor manufacturing") AND ("wastewater" OR "effluent")
Google Scholar	("heavy metals" OR "contamination" OR "pollutant") AND ("common heavy metals" OR "frequent heavy metals") AND ("found" OR "detected OR observed") AND ("semiconductor industrial" OR "semiconductor manufacturing") AND ("wastewater" OR "effluent" OR "sewerage" OR "waste") AND ("causes" OR "reasons") AND ("existence" OR "presence"))

Table 2. 8 Full search string for the review question 2

Database	Search String
Scopus	TITLE-ABS-KEY (("ion exchangers" OR "anion exchangers" OR "cation exchangers") AND ("heavy metals" OR "contamination" OR "pollutant") AND ("mechanism" OR "process" OR "technique" OR "measure") AND ("semiconductor industrial" OR "semiconductor manufacturing") AND ("wastewater" OR "effluent" OR "sewerage" OR "waste"))
Science Direct	("ion exchangers" OR "cation exchangers" OR "cation exchangers") AND ("heavy metals") AND ("mechanism") AND ("semiconductor industrial") AND ("wastewater" OR "effluent")
Google Scholar	(("ion exchangers" OR "cation exchangers" OR "cation exchangers") AND ("heavy metals" OR "contamination" OR "pollutant") AND ("mechanism" OR "process" OR "technique" OR "measure") AND ("semiconductor industrial" OR "semiconductor manufacturing") AND ("wastewater" OR "effluent" OR "sewerage" OR "waste"))

Table 2. 9 Full search string for the review question 3

Database	Search String
Scopus	TITLE-ABS-KEY (("resin ion" OR "ion exchange" OR "anion resin" OR "cation resin") AND ("application" OR "function" OR "operation") AND ("mechanism" OR "process" OR "technique" OR "measure") AND ("adsorbent"))
Science Direct	("resin ion" OR "ion exchange" OR "anion resin" OR "cation resin") AND ("application") AND ("mechanism" OR "process") AND ("adsorbent")
Google Scholar	(("resin ion" OR "ion exchange" OR "anion resin" OR "cation resin") AND ("application" OR "function" OR "operation") AND ("mechanism" OR "process" OR "technique" OR "measure") AND ("adsorbent"))

Table 2. 10 Full search string for the review question 4

Database	Search String
Scopus	TITLE-ABS-KEY (("resin" OR "chemical materials" OR "synthetic" OR "vicious substances") AND ("adsorbent") AND ("removal" OR "discharge" OR "elimination" OR "eradication") AND ("semiconductor industrial" OR "semiconductor manufacturing") AND ("wastewater" OR "effluent" OR "sewerage" OR "waste") AND ("ion exchange" OR "cation exchangers" OR "anion exchangers") AND ("process" OR "mechanism" OR "technique" OR "measure"))
Science Direct	("resin") AND ("adsorbent") AND ("removal") AND

	("semiconductor industrial") AND ("wastewater) AND ("ion exchange" OR "cation exchangers" OR "anion exchangers") AND ("process”)
Google Scholar	(("resin" OR "chemical materials" OR "synthetic" OR "vicious substances") AND ("adsorbent") AND ("removal" OR "discharge" OR "elimination" OR "eradication") AND ("semiconductor industrial" OR "semiconductor manufacturing") AND ("wastewater" OR "effluent" OR "sewerage" OR "waste") AND ("ion exchange" OR "cation exchangers" OR "anion exchangers") AND ("process" OR "mechanism" OR "technique" OR "measure"))

The screening process is the second step in the systematic research process, and it establishes the criteria for selecting or eliminating papers for evaluation. Both of the listed papers must be checked for inclusion and exclusion criteria. The search can be carried out automatically using the database sorting function that has been selected. Timelines, publishing formats, and terminology are all important factors to consider when deciding whether or not to include something.

Because researchers are nearly unable to analyze all of the papers currently released (Okoli, 2015), it is suggested that researchers decide the timeline range to be evaluated. Only papers of scientific data published in journals, research publications, or review articles were used to ensure the study's quality. To avoid a fundamental misunderstanding, the study solely includes materials written in Bahasa Malaysia and English. Table 2.11 lists some of the study's inclusion and exclusion criteria.

Table 2. 11 Inclusion and exclusion criteria

Criteria	Inclusion	Exclusion
Timeline	2016-2021	Before 2016
Publication Type	Journal, Research article, Review article, Books, Conference proceeding, Chapter in Book	Newspaper
Language	English, Bahasa Malaysia	Other than English and Bahasa Malaysia

The final subprocess is eligibility, in which the authors manually reviewed the papers collected to confirm that all other papers met the screening criteria. The titles and abstracts of the papers are available to read. The contents of the articles selected for review must be reviewed if the relevance of the articles is not yet evident.

2.3.2 Data extraction and synthesis

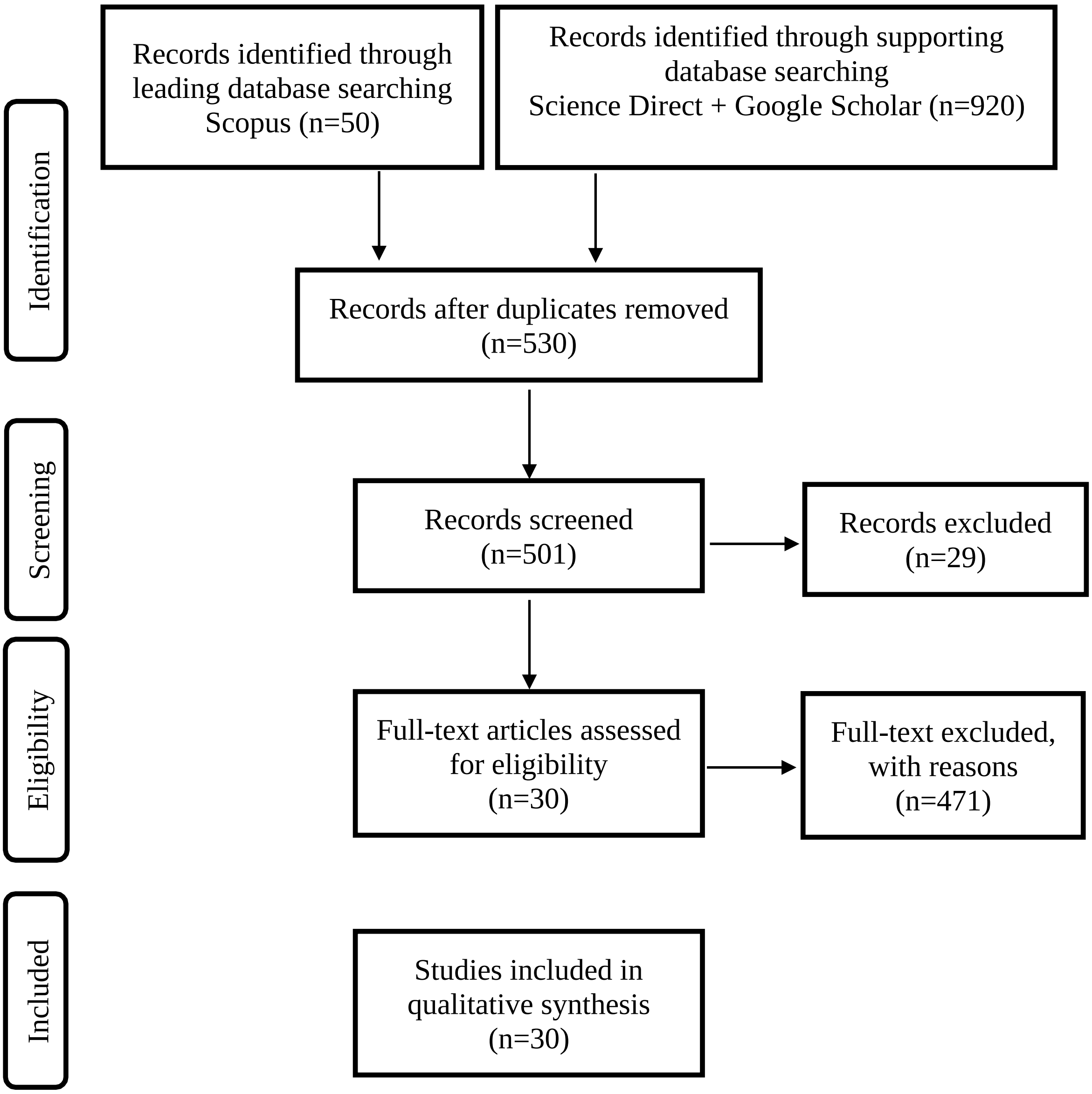
The following move is to collect and examine the data included in the following papers after all articles have been categorised for systematic analysis. The literatures also described a number of approaches used for the extraction of data and the synthesis frameworks and procedures, although non-meta-analysis was commonly utilized as qualitative analytics and meta-analysis as quantitative analytics. A description of the results tables for a non-meta-analysis will be produced. Meanwhile, data pools and advanced statistical processing are part of a meta-analysis.

Despite recent advances in machine learning models for automating data extraction in systematic reviews, data extraction is still mostly a manual process.

2.4 Reporting SLR

At this time, all processes must be documented. From identification to screening, everything should be properly recorded and result in eligibility. A PRISMA flow diagram is suggested for displaying the number of papers recovered. Figure 2.2 depicts the situation.

Figure 2.2 Flow diagram of the retrieved articles



CHAPTER 3

DATA EXTRACTION AND SYNTHESIS/ANALYSIS/METHODOLOGY

3.1 Introduction

The data from the selected publications was classified into details and conclusions as part of the extraction and synthesis procedure. Data was extracted via identifying and extracting data from the publications that were chosen. The synthesized information, the retrieval of important material, and the conclusion of the selected publications were all examined during the study process.

In order to reach the SLR's purpose, the element of interest was arranged based on the basic features of the articles and the major criteria employed for the assessment. Years, the type and scope of the research, and the country in which the study was done are all included in the basic information in these articles. The data for each selected document is collected into an Excel table for data analysis. The categorization step sorted and processed the data collected in preparation for further investigation. During the analysis phase, the evaluation questions would yield replies. It includes a qualitative analysis of the findings, a synopsis of the next steps, and a conclusion for future research. The details from the final list can be summarized in a simple manner.

3.2 Data extraction

In order to analyze and evaluate the results, this approach needs the examination of data from similar trials. When extracting data, proper data management practices must be followed. Data management can start as soon as the data is collected, and it can also analyze which types of data to keep from among the many alternatives accessible in data management tools like Mendeley, Zotero, EndNotes, NVivo, and ATLAS.ti.

Data extraction is the process of reading the full text of each article chosen for inclusion in the study and extracting the pertinent data using a prescribed data extraction form or table. A data extraction form or table can be created using an Excel or Google spreadsheet or a Word document for smaller or easier jobs. Based on the review objectives and review questions generated in the first phase of the SLR, the data extraction form or table is created.

Iterative processes are commonly used to collect qualitative data. Review authors may alternate reading primary articles, data extraction, and synthesis/interpretation when relevant themes and issues arise from the synthesis (Noyes & Lewin, 2011). To summarize the literature evaluated, the data extraction table is generally utilized in the thesis or dissertation.

3.2.1 Descriptive data

This part focuses on the descriptive data for all of the papers that will be analyzed. The name, title, year, and publishing type information, as well as the publication outlet, are highlighted in this table. The year extends from 2015 to 2021, and the sorts of publications are divided into journals, papers, book chapters, and prior conferences. Each paper is made up of material gathered under certain study objectives and the extent of the investigation. To make the discussion in Chapter 4 easier, the brief descriptions and methodology used for each selected paper are provided in this table.

Author, Title of Publication	Year of Publication	Types of Publication	Publication outlet	Research objectives	Research scope	Brief description (synopsis)	Methods
Gunatilake.S.K, Methods of Removing Heavy Metals from Industrial Wastewater	2015	Journal	Google Scholar	RQ1	RQ1	RQ1	Physio-chemical treatments
T. M.Zewail, N.S.Yousef, Kinetics Study of Heavy Metal Ions Removal by Ion Exchange in Batch Conical Air Spouted Bed	2015	Journal	Google Scholar	RQ4	RQ4	RQ4	Ion exchange
Yogeshwar N. Thakare, Arun Kumar Jana, Performance of High-Density Ion Exchange Resin (Indion225H) For Removal Of Cu (II) From Waste Water	2015	Journal	Google Scholar	RQ4	RQ4	RQ4	Ion exchange resin

Mohsen Arbabi, Sara Hemati, Masoud Amiri, Removal of Lead Ions from Industrial Wastewater: A Review of Removal Methods	2015	Journal	Google Scholar	RQ1	RQ1	RQ1	Ion exchange process
Meihua Zhao, Ying Xu, Chaosheng Zhang, Hongwei Rong, Guangming Zeng, New Trends in Removing Heavy Metals from Wastewater	2016	Review Article	Google Scholar	RQ2	RQ2	RQ2	Ion exchange process
P. C.C. Siu, L.F. Koong, J. Saleem, J. Barford, G. Mckay, Equilibrium and Kinetics of Copper Ions Removal from Wastewater by Ion Exchange	2016	Journal	Google Scholar	RQ2/RQ3	RQ2/RQ3	RQ2/RQ3	Ion exchange process

Jia Qian, Zuoxiang Zeng, Weilan Xue, Qiongge Guo, Lead Removal from Aqueous Solutions By 732 Cation-Exchange Resin	2016	Journal	Google Scholar	RQ3/RQ4	RQ3/RQ4	RQ3/RQ4	Cation exchange resin
Serpil Edebali, Erol Pehlivan, Evaluation of Chelate and Cation Exchange Resins to Remove Copper Ion	2016	Journal	ScienceDirect	RQ2/RQ3	RQ2/RQ3	RQ2/RQ3	Chelate and cation exchange resins
Sunghwan Bang, Jae-Woo Choi, Kangwoo Cho, Chongmin Chung, Hojeong Kang, Seok Won Hong, Simultenous Reduction of Copper and ToxicityiIn Semiconductor Wastewater Using Protonated Alginate Beads	2016	Journal	ScienceDirect	RQ1	RQ1	RQ1	Protonated alginate beads

Ilda Vergili, Z. Beril Gönder, Yasemin Kaya, Gülten Gürdagˇ, Selva Cavus, Sorption of Pb (Ii) From Battery Industry Wastewater Using A Weak Acid Cation Exchange Resin	2017	Journal	ScienceDirect	RQ2/RQ3	RQ2/RQ3	RQ2/RQ3	Weak acid cation exchange resin
Jun-Jie Tan Et Al, Ion Exchange Resin on Treatment of Copper and Nickel Wastewater	2017	Conference Proceeding	Google Scholar	RQ4	RQ4	RQ4	Ion exchange resin
Iyyanki V.Muralikrishna, Valli Manickam, Industrial Wastewater Treatment Technologies, Recycling and Reuse	2017 Pg (312-315)	Chapter in Books	ScienceDirect	RQ2	RQ2	RQ2	Various treatment
Tahir M.T, Badamasi H and A.K. Suleiman,	2017	Journal	Google Scholar	RQ1	RQ1	RQ1	Physio-chemical treatment