平成27年度我が国循環産業海外展開事業化促進業務
マレーシア国における廃棄物の再資源化事業

報告書

平成28年3月

アミタ株式会社

はじめに

経済のグローバル化や人口増加に伴い、世界規模での自然災害や環境問題が顕在化してきている。中でも経済活動に伴う産業廃棄物の発生量の増加と不適正処理による問題は同様に世界的な課題となっており、各国行政の適切な対応と適正な処理技術や健全な環境産業の育成が求められている。この傾向は、IMF の報告の通り、2009 年に 15 兆ドルに達したアジア経済が 2015 年には 24.4 兆ドルに達し、NAFTA や EU を超える経済圏になろうとしているアジア諸国において特に顕著であり、早期の対策が求められている。その中でもマレーシア政府は 2020 年までに先進国入りすることを目指した中期計画である「WAWASAN2020」の中で、「廃棄物のリサイクル率を 22%まで向上させる」目標を明確に打ち出し、環境対策に具体的に動き出している。2001 年に制定された"The Third Outline Perspective Plan (2001-2010)"では、「ゼロ・エミッション技術の利用を促進し、エネルギー消費の削減や廃棄物再利用および再生方針」が打ち出され、第 10 次マレーシア計画（2011-2015）においては、「再生不可能な資源の持続的マネジメント、グリーン技術の生産・加工工程への導入」が戦略の一つとして明記されている。しかし、マレーシア天然資源環境省・環境局が発表した報告を見る限りでは、発生する廃棄物の 90%以上が依然、単純焼却・埋立処理されており、上述の方針が具体的に進んでいないのが現状の様である。

そこで「マレーシア国における廃棄物の再資源化事業」（以下、本事業と記す。）では、現在マレーシア政府が進めるグリーン戦略の考えに基づき、製造工場から排出される固形廃棄物を原料に、独自の混合技術でセメント製造工場向けに SiO2 と Al2O3 を主成分とするセメント代替原料を製造する。具体的には、マレーシアにおける指定廃棄物のうち、特に汚泥、燃え殻、ばいじん、廃触媒等をセメント代替原料製造の対象廃棄物としている。本事業では、39 年にわたる再資源化事業を通して蓄積された 10,000 種を超える廃棄物の分析データおよび情報管理ノウハウを用い、廃棄物の特徴である成分、性状、発生量等の不安定要素を、品質を均一にして安定的なセメント代替原料として供給することを目指している。再資源化工程においては、火、水、および化学薬品は一切使用せず、また 2 次廃棄物が発生しない 100%再資源化システムである。そのため、大気汚染、水質汚濁、温室効果ガス発生による環境負荷が極めて小さい。更に、本事業を通じて 3R の推進のみならず、マレーシアにおける廃棄物管理の透明性を高め、近年増加している不法投棄、不適正処理の削減、それらによって生じる環境汚染リスク低減に貢献することを目指すものである。

Summary

The environmental issues have become evident on a worldwide scale in tandem with the economic globalization and increasing populations. In particular, the increases in industrial wastes, both in terms of amounts and varieties, resulting from economic activities have become an equally important issue worldwide and, therefore, each country's administration is required to take appropriate actions and to foster proper processing technology and sound environmental industries. As depicted in the IMF Report, this tendency is particularly pronounced among Asian countries which are becoming an economic bloc even greater than the NAFTA or the EU: The economic scale there reached $15 trillion in 2009 and, further, to $24.4 trillion in 2015. As a consequence, measures are required to be taken at an early stage. Among such movements, the Malaysian Government has worked out its target of "raising the rate of waste recycling to 22%" in its WAWASAN 2020, a medium-term project in which the country aims at becoming one of the advanced nations by 2020, and has begun implementing concrete environmental measures. In The Third Outline Perspective Plan (2001-2010) which was established in 2001, the Malaysian Government hammered out its principle of "promoting utilization of the zero-emission technology to reduce energy consumption and to increase re-use and recycling of wastes." In the tenth Malaysian Project (2011-2015) also, it is clearly stated as one of the strategies to "manage continuously the unrecyclable resources and introduce the green technology into the production and processing." And yet, as far as the report by the Department of Environment of the Malaysian Ministry of Natural Resources and Environment is concerned, more than 90% of the wastes generated there are simply disposed of by incineration or landfill even now; the abovementioned principle does not seem to be in progress.

Against such backdrop, in the "Project of Recycling Wastes into Resources in Malaysia" (which will hereafter be referred to as "the Project"), it is intended that we will produce the alternate raw materials (hereafter referred to as "ARM") containing principal ingredient of SiO_2 and Al_2O_3 for cement plants, applying our unique blending technology to the solid wastes generated in manufacturing plants, based on the idea of the "green" strategy which the Malaysian Government is promoting. More specifically, it is projected that, among the Scheduled Wastes (hereafter referred to as "SW") in Malaysia, sludge, cinders, soot particles, waste catalysts, etc. will be used as materials for making ARM. In the Project, SW will be converted into useful materials for

cement plants by eliminating such uncertain factors as those pertaining to ingredients, properties, amounts generated, timing of generation, etc., which are characteristic to wastes, through properly blending them and making them homogeneous to stabilize their supply. In this process, we will apply the analytical data of wastes and the information management knowhow built up through the analysis of more than 10,000 kinds of wastes gained in the 38 years of recycling business. In such a recycling process, no fire, no water and no chemicals are used. It is a 100% perfect recycling system without generating secondary wastes. As the result, its environmental burden, which may be caused by atmospheric pollution, water contamination or CO_2 emission, is extremely limited. Furthermore, it is also targeted that the Project will, in addition to the promotion of the "3 Rs," heighten the transparency of the waste management, reduce the illegal dumping or improper processing, which have recently increased, and contribute to the lessening of the risk of environmental pollution to be caused by these.

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1.　事業の目的・概要

1.1 事業目的

経済のグローバル化や人口増加に伴って、世界規模で環境問題が顕在化している。中でも経済活動に伴う産業廃棄物の発生量の増加と多様化は同様に世界的な課題となっており､各国行政の適切な対応と適正な処理技術や健全な環境産業の育成が求められていると｡この傾向は、IMF の報告の通り、2009 年に 15 兆ドルに達したアジア経済が 2015 年には 24.4 兆ドルに達し、NAFTA や EU を超える経済圏になろうとしているアジアにおいて特に顕著であり、早期の対策が求められている。その中でも、マレーシア政府は 2020 年までに先進国入りすることを目指した中期計画である「WAWASAN2020」の中で､「廃棄物のリサイクル率を 22%まで向上させる」目標を明確に打ち出し､環境対策に具体的に動き出している。2001 年に制定された“The Third Outline Perspective Plan (2001-2010)”では､「ゼロ・エミッション技術の利用を促進し､エネルギー消費の削減や廃棄物再利用および再生方針」が打ち出され､第 10 次マレーシア計画（2011-2015）においては､「再生不可能な資源の持続的マネジメント､グリーン技術の生産･加工工程への導入」が戦略の一つとして明記されている。しかし､マレーシア天然資源環境省･環境局が発表した報告を見る限りでは､発生する廃棄物の 90%以上が依然、単純焼却・埋立処理されており、先述の方針が具体的に進んでいないのが現状の様である。本業務は、「平成 27 年度我が国循環産業海外展開事業化促進業務（III.事業案件形成調査)」として、セランゴール州、ペナン州を含むマレーシア半島各州の製造工場から排出される汚泥や燃え殻の固形廃棄物を主原料とし､セメント工場向け代替原料を製造する。廃棄物再資源化製造所の建設対象地域はセランゴール州とする。本事業を通して廃棄物 3R を推進すると同時に、マレーシア国における廃棄物の不適正処理による環境負荷低減に貢献する。

現地においては､①指定廃棄物（Scheduled Waste : 以下 SW と記す｡）の最終処分（Off-site Treatment）許可を取得している企業はマレーシア半島で一社、サバ・サラワク州で一社のみであり、またその処理費用が高額であること、②Off-site Recovery（リサイクルに近いが二次廃棄物を先述の最終処分場へ搬入することが前提）の許可を保有する処理企業も増えてはいるものの､二次廃棄物の処理が適正に行われていないなどその透明性に問題が生じていること､③二次廃棄物を排出しない完全再資源化事業に該当する適当な許可が存在せず､マレーシア国天然資源環境省環境局（Ministry of Natural Resources and Environment, Department of Environment：以下 DOE と記す｡）からの許可取得に時間を要していること、④製造所建設時の 環境アセスメント（Environmental Impact Assessment：以下 EIA と記す｡）に長期の時間を要していること、⑤不必要に厳格な受け入れ基準が各セメント会社と DOE との間で取り決められていること､⑥排出事業者の委託先変更に係る行政手続きに半年以上の時間を要すること等､多くの課題が存在する。このような状況を踏まえ､本業務は産業系廃棄物（固形）からセメント製造工場向けの代替原料を製造することで、廃棄物の 3R 促進を図り、マレーシア国における廃棄物不適正処理による環境負荷低減と循環型社会形成に寄与するものと考えている。下記に本事業の事業概略図を示す。

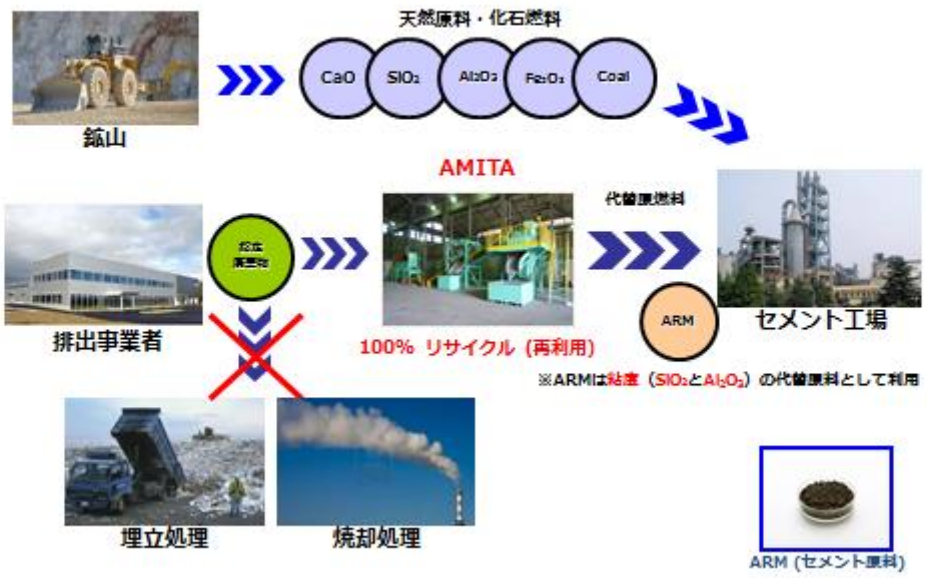


図 1.1 (1) 事業の概略図

又、本事業の実施体制は下記の通りである。

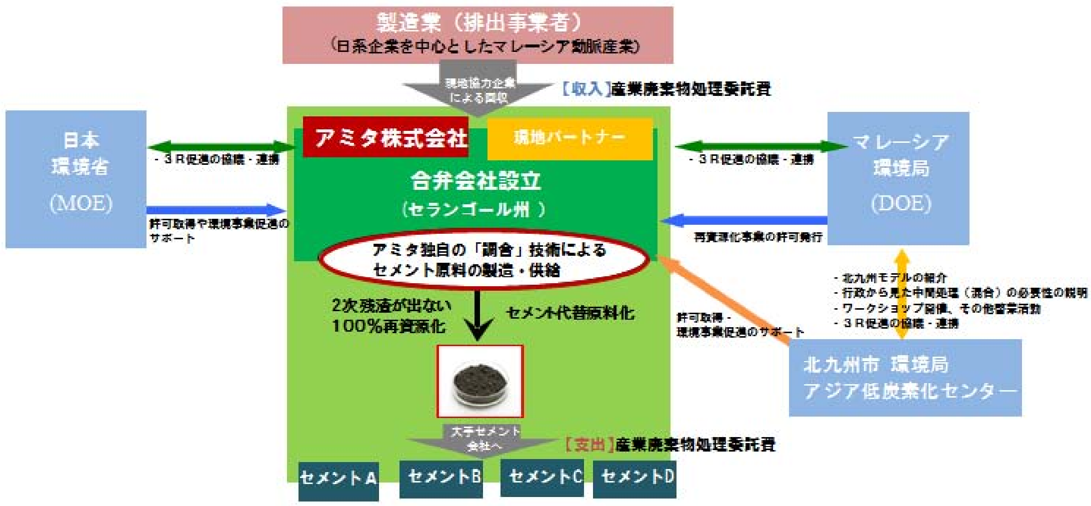


図 1.1 (2) 事業の実施体制

1.2 事業概要

本事業は、現在マレーシア政府が進めるグリーン戦略の考えに基づき、製造工場から排出される固形廃棄物を原料に、独自の混合技術でセメント製造工場向け SiO2 と Al2O3 を主成分とする粘土代替原料（Alternative Raw Material：以下 ARM と記す。）を製造する。具体的

には、マレーシアにおける指定廃棄物（Scheduled Waste：以下 SW と記す。）のうち、特に汚泥、燃え殻、ばいじん、廃触媒等を ARM 原料の対象としている。本事業では、38 年にわたる再資源化事業を通して蓄積された 10,000 種を超える廃棄物の分析データおよび情報管理ノウハウにより、廃棄物の特徴である成分、性状、発生量、発生時期等の不安定要素を、適正に混合し、品質を均一にして供給量を安定させることにより、それら不安定要因を取り除くことでセメント製造工場向けに SW を原料化するものである。再資源化工程においては、火、水、および化学薬品は一切使用せず、また 2 次廃棄物が発生しない完全なる 100%再資源化システムである。そのため、大気汚染、水質汚濁、CO2 排出による環境負荷が極めて小さい。更には、本事業を通じて 3R の推進に留まらず、廃棄物管理の透明性を高め、近年増加している不法投棄、不適正処理の削減、それらによって生じる環境汚染リスク低減に貢献することを目指すものである。本事業の対象地域は次の通りである。

【対象地域】
循環資源製造所の建設予定地：セランゴール州
廃棄物の収集対象地域：セランゴール州、ペナン州を中心にマレー半島の各州

又、本事業が目指す廃棄物処理の流れを図 1.2.に示す。

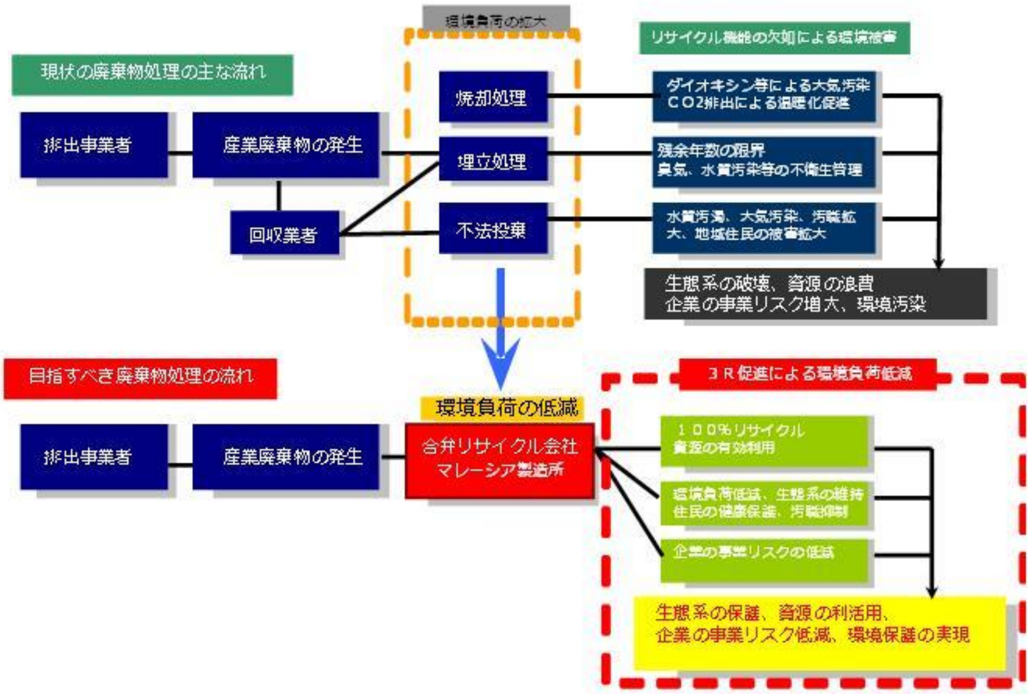


図 1.2 (1) 本事業が目指す廃棄物処理の流れ

ARM は、汚泥や燃え殻、ばいじん等の固形産業廃棄物をユーザーの規格に合致するよう調合したセメント代替原料である。発熱量の低い ARM はセメント工場で主に粘土の代替原料として使用され、発熱量の高いセメント代替燃料（Alternative Fuel：以下、AF と記す。）は焼成工程において仮焼炉で使用される。ARM、AF 燃焼後の燃え殻はクリンカに混合されるため、二次廃棄物が発生しない完全な再資源化が可能である。

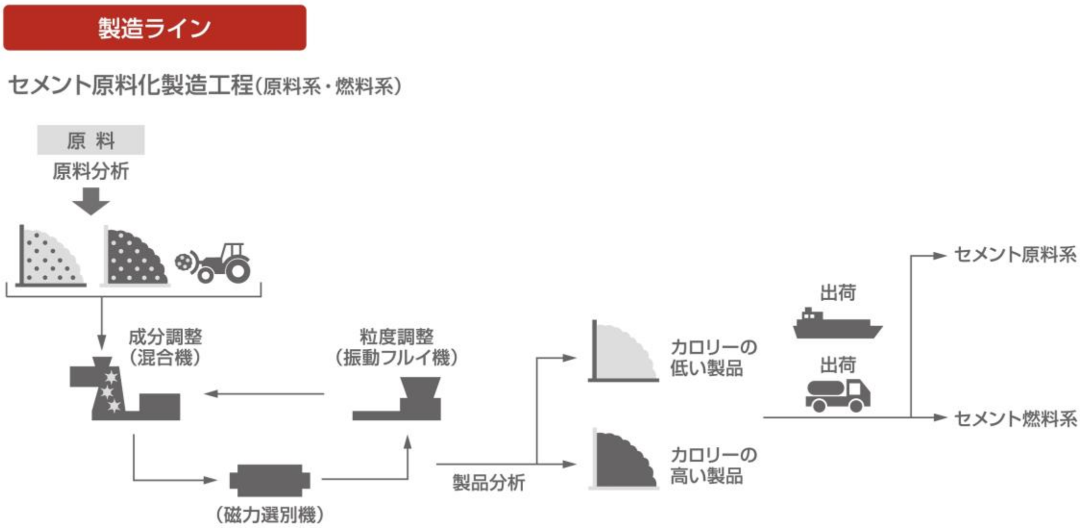


図 1.2 (2)　セメント原燃料化の製造工程

リサイクル実績量 (t)	2007 年度	2008 年度	2009 年度	2010 年度	2011 年度	2012 年度	2013 年度	2014 年度
スラミックス® (液体燃料)	23,090	25,766	21,857	22,902	21,833	19,287	18,007	17,471
セメント原料系	20,781	26,788	33,805	33,300	31,578	30,788	27,994	61,324
セメント燃料系	45,117	71,886	75,636	80,312	92,930	86,557	88,379	59,303
合計	88,988	124,440	131,298	136,514	146,341	136,632	134,380	138,098

図 1.2 (4)　製造実績（数値は日本国内 4 拠点の合計）

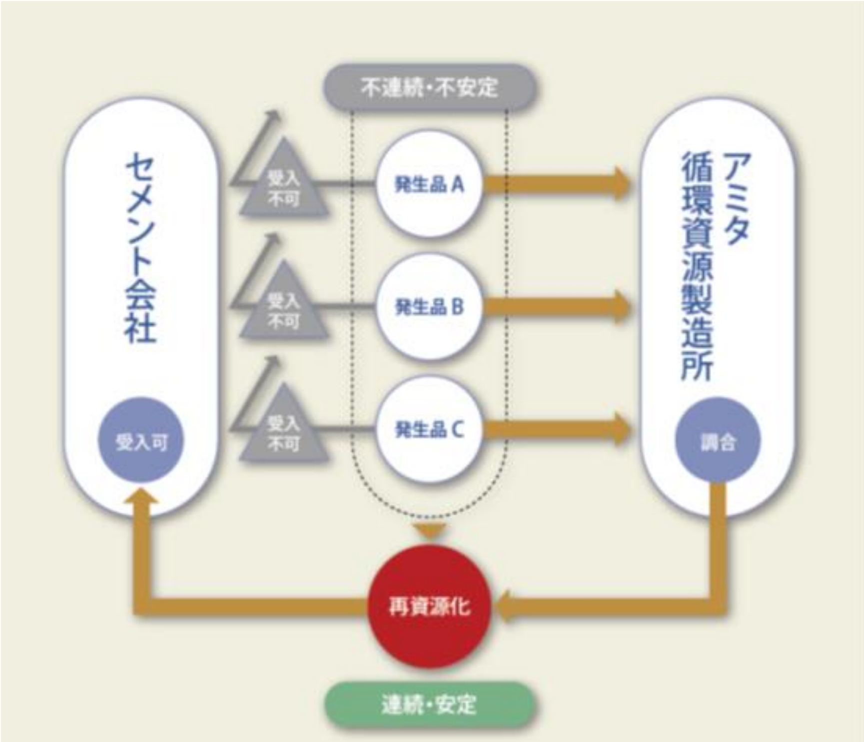


図 1.2 (3)　廃棄物の受入イメージ図

不連続でかつ不安定な廃棄物を連続でかつ安定的な資源にするのが本事業の役割である。製造業から排出される発生品はその成分（重金属、塩素等のセメント忌避成分）や数量、立地条件等によってセメント会社で直接受入できないものがある。そうした複数の発生品を当該事業を通じて混合･調合することで､セメント会社での受入可能な再資源化製品を製造し、再資源化ネットワークを構築することが可能になる。

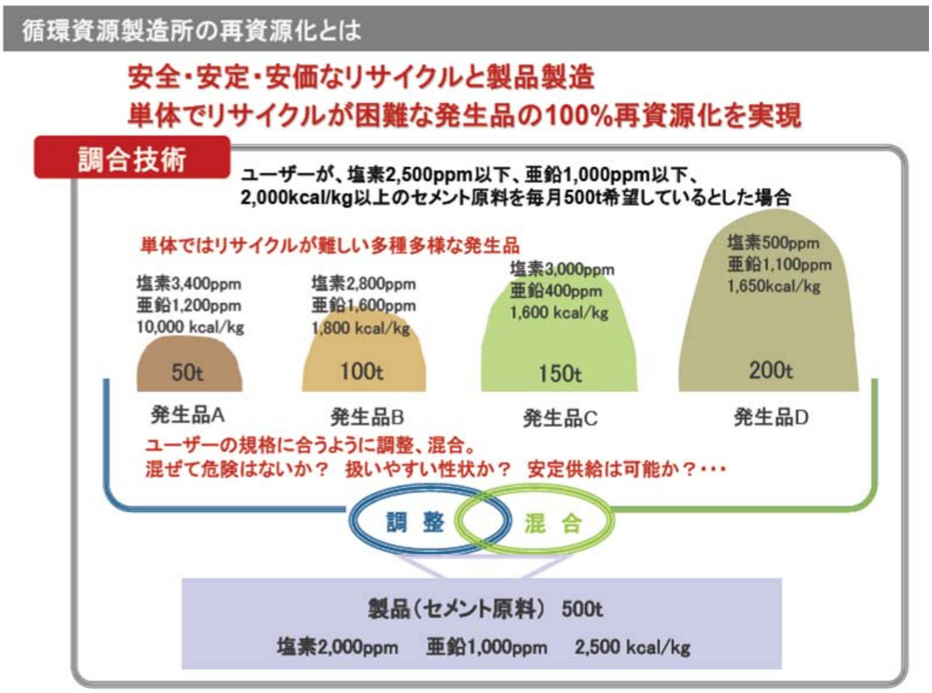


図 1.2.(4)　混合技術の仕組み

ARM は汚泥や燃え殻、ばいじんなどの産業廃棄物をユーザーの規格に合致するよう調合したセメント代替原料である。熱量の低い ARM はセメント工場で主に粘土（SiO_2、Al_2O_3）代替として使用され、熱量の高い AF は焼成工程において仮焼炉で使用される。ARM は他のセメント原料と共に 1,450℃の高温で焼成されるため、ダイオキシン等の有害物質も炉内で分解される。又、不燃物と焼成後の燃え殻は原料としてはクリンカに移行し、可燃物は燃料として活用されるため、新たな二次廃棄物が発生しない完全な再資源化が可能である。

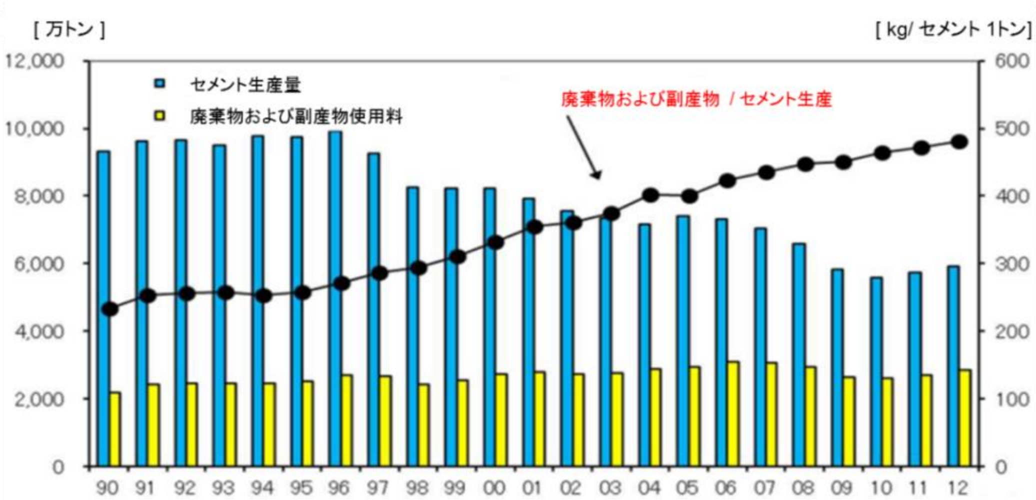


図 1.2.(5)　セメント生産量と廃棄物・副産物使用量、使用原単位の推移

（参照：一般社団法人セメント協会）

日本のセメント産業は、原料及び燃料としての廃棄物有効利用に積極的に取り組んでおり、2013 年度には年間約 4 億 t 排出される産業廃棄物及び副産物のうち 3,000 万 t 以上がセメント製造時の代替原燃料として活用されている。セメント 1t あたりの産業廃棄物使用原単位は 486kg と世界でも最高水準であり、日本における廃棄物の利活用及び適正処理において重要な役割を担っている。

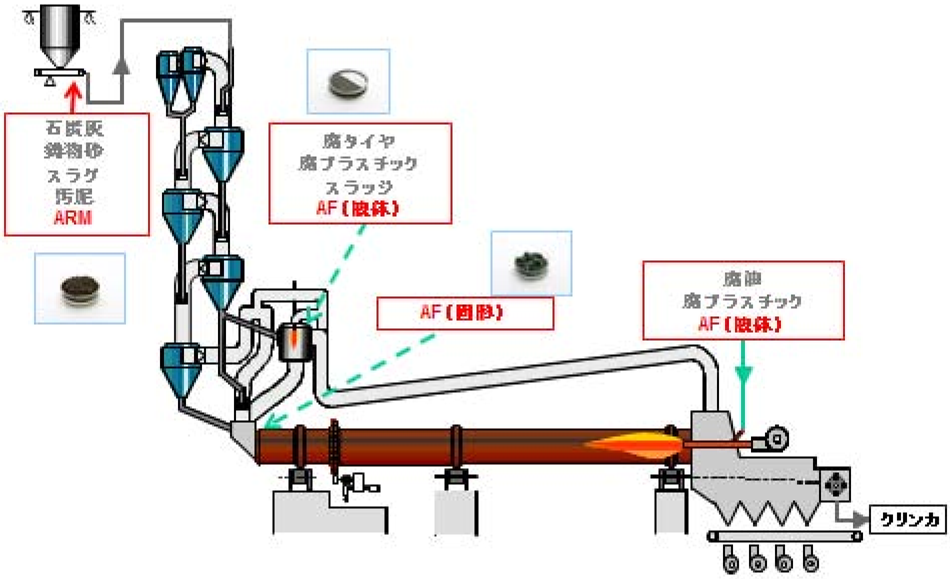


図 1.2.(6)　セメントの焼成工程と ARM、AF の投入場所

2.　海外展開計画案の策定

セランゴール州、ペナン州を含むマレーシア半島各州の製造工場から排出される汚泥や燃え殻の固形廃棄物を主原料とし、セメント工場向け代替原燃料を製造する事業について、導入規模を仮に設定した上で、事業計画案を下記に示す。

【導入規模】
敷地面積：20,300 ㎡
処理能力：3,520t/月（セメント原燃料化処理）
工場第一期（2017 年予定）：　混合機、磁選機、振動ふるい機導入
工場第二期（2020 年予定）：　破砕機、粉砕機導入
工場第三期（2023 年予定）：　高含水受入ライン、紛体物受入ライン導入

【処理対象廃棄物種類】
各種製造業の工場から発生する指定廃棄物(Scheduled Waste　：以下、SW と記す。) のうち、特に汚泥、燃え殻、ばいじん、廃触媒等の固形廃棄物を対象品とする。

【許可申請予定の SW コード】

SW104（Dust, Slag, and Ash）【ダスト、スラグ、及び灰】
SW110（Glass Cullet）【ガラスくず】
SW202（Waste Catalyst）【廃触媒】
SW203（Stabilized Sludge）【固化汚泥】

SW204（Water Treatment Sludge）【排水処理汚泥】
SW207（Fluoride Sludge）【フッ酸汚泥】
SW310（Tank Sludge）【タンクスラッジ】
SW311（Oil Sludge）【含油汚泥】
SW316（Acid Sludge）【水酸化汚泥】
SW319（Phenol Contaminated Sludge）【フェノール汚泥】
SW321　(Rubber or Latex Sludge Sludge)　【ゴム汚泥】
SW406（Slag and Ash）【指定廃棄物の焼却後に発生するスラグ、及び灰】
SW416（Paint Sludge）【ペイントスラッジ】
SW427（Mineral Sludge）【無機汚泥】の 14 種である。

尚、日本国内では ARM のみならず廃棄物を利用した AF の製造を行っているが、マレー半島で埋立・焼却の許可を唯一保有する Kualiti Alam Sdn Bhd（以下、KA 社）がマレーシア政府との間で独占契約を締結しているため、AF に適している熱量の高い廃棄物の取扱いはその契約に抵触する可能性がある。又、セメント会社側での受入については、AF より ARM の方が利用しやすい点もあり、事業開始時は ARM のみの製造から始めることを検討している。この KA 社と政府の独占契約は 2015 年 2 月中に失効期限を迎えたが、現在も KA 社は操業を続けており、今後の独占事業に対する政府の見解は出されていない。AF 事業については、今後の展開の可能性も見据え、情報収集を行いながら慎重に計画する必要がある。下記に ARM 事業の計画している導入規模を示す。

【事業実施体制】
現地パートナーとアミタ現地法人との合弁会社

【事業展開スキーム】
今後の AF 事業展開も見据え、破砕機、粉砕機、紛体サイロ、高含水ライン等の設備増設を検討する。また、許認可の取得状況によって液体燃料（Slurry Mix：以下、SMX）の製造事業の拡張も検討する。

3. 対象地域における現状調査、廃棄物の組成・性状調査

① 排出事業者のニーズ調査

排出事業者のニーズ把握のため、排出事業者への訪問調査を継続して実施し、廃棄物の排出量、種類、処理委託先、処理単価、処理における現状の課題等の情報収集を行った。又、廃棄物の組成・性状調査を進めるため、新たに 10 種類の廃棄物のサンプルを採取し、過去に独自で実施したサンプル取得数と合わせて約 110 種類のサンプリングが完了した。分析結果は都度、排出事業者にフィードバックを行った。実際に訪問した排出事業者からはコストダウン、適正処理、リサイクル率向上のニーズが非常に高く、本事業の進出を希望される排出事業者は非常に多い結果となった。詳細は、表 3.1.(5)　KA 社の処理費用を参照できるが、一般的に排出事業者が KA 社に支払っている処理費は、埋立処理で約 500RM/トン、固形化処理で約 800RM/トン、焼却処理で 1,500～3,800RM/トンとなっている。

表 3.1.(1)　排出事業者調査リスト

No	業種	該当SWｺｰﾄﾞ	発生品名	発生量(t/月)	ｻﾝﾌﾟﾙ有無
1	自動車部品	204	乾燥汚泥	2	有
2	自動車部品	204	ショットブラスト	1	有
3	電子部品	204	排水処理汚泥	1	有
4	電子部品	207	フッ素汚泥	0.6	有
5	電子部品	427	使用済み研磨パウダー	3	有
6	電子部品	427	研磨屑	1	有
7	電子部品	427	ピット清掃汚泥	1	有
8	電子部品	427	排水処理汚泥	1	有
9	レンズ	204	排水処理汚泥	5	有
10	情報通信機械器具	316	研磨汚泥	5	有
11	情報通信機械器具	316	排水処理汚泥	2	有
12	情報通信機械器具	316	ペイント汚泥	2	有
13	電子部品	204	排水処理汚泥	2	有
14	自動車部品	104	はんだドロス	不明	無
15	自動車部品	104	はんだドロス	不明	無
16	自動車部品	204	切削時の金属屑(鉄)を含む汚泥	1	有
17	電子部品	204	ペイント汚泥	5	有
18	電子部品	204	ペイント汚泥	5	有
19	自動車部品	204	水酸化汚泥	10	有
20	自動車関連	204	金属水酸化汚泥	8	有
21	自動車関連	204	金属汚泥	8	有
22	自動車関連	427	リン酸汚泥	2	有
23	情報通信機械器具	204	シリカスラッジ	100	無
24	情報通信機械器具	204	排水処理汚泥	3	有
25	半導体関連	104	ドロス	不明	無
26	半導体関連	204	汚泥	不明	無
27	半導体関連	316	フッ酸汚泥	不明	無
28	自動車部品	204	水酸化研磨汚泥	11	有
29	自動車部品	204	排水処理汚泥	1	有
30	情報通信機械器具	104	酸化アルミニウム（ブラスト）	0.016	有
31	情報通信機械器具	204	イオン交換樹脂	0.004	有
32	情報通信機械器具	104	煙道ダスト	40	有
33	情報通信機械器具	104	ファイバーくず	40	有
34	自動車部品	204	アルミ汚泥	20	無
35	自動車部品	104	焼却灰	0.03	無
36	自動車部品	204	ペイント工程からの汚泥	2	無
37	電子部品	204	排水処理汚泥	1	有
38	電子部品	104	ブラストくず	1	無

39	電子部品	104	Al ダスト	0.3	有
40	電子部品	204	排水処理汚泥（フィルタープレス）	25	有
41	電子部品	204	排水処理汚泥（Auto Separator)	25	有
42	家電機器	204	水酸化汚泥	3	有
43	家電機器	204	排水処理汚泥	1	有
44	家電機器	104	Fe ドロス	100	有
45	家電機器	104	Al ドロス	3	有
46	家電機器	104	回収ダスト	250	有
47	家電機器	104	ショットブラストダスト	250	有
48	エネルギー関連	207	フッ酸汚泥	120	有
49	家電機器	204	Niスラッジ	10	有
50	自動車関連	207	フッ酸汚泥	5	有
51	自動車関連	427	リン酸汚泥	20	有
52	半導体部品	204	活性汚泥	70	無
53	半導体部品	204	排水処理汚泥	30	無
54	電子部品	104	Fe ダスト	0.012	有
55	電子部品	204	Al 汚泥	60	有
56	電子部品	204	研磨汚泥	8	有
57	自動車部品	204	金属水酸化汚泥	0.2	有
58	自動車関連	204	排水処理汚泥	10	有
59	電子部品	204	Al 汚泥	100	有
60	電子部品	204	有機汚泥	20	有
61	自動車関連	204	排水処理汚泥	10	有
62	自動車関連	204	排水処理汚泥	3	有
63	自動車関連	427	リン酸汚泥	2	無
64	一般消費財	204	排水処理汚泥	100	有
65	化学関連	204	排水処理汚泥	2	有
66	化学関連	適用外	クリンカ	30	有
67	一般消費財	406	焼却灰	14	有
68	一般消費財	204	ASM汚泥	25	有
69	一般消費財	適用外	ラグーン汚泥	2500	有
70	一般消費財	204	石鹸汚泥	70	有
71	一般消費財	204	石鹸汚泥	30	有
72	一般消費財	325	廃レジン	30	有
73	一般消費財	適用外	バイオ汚泥	200	有
74	電子部品	204	Ni汚泥	10	有
75	電子部品	207	F汚泥	50	有
76	電子部品	204	シリカ汚泥	3	有
77	自動車部品	適用外	強化ガラスくず	140	有
78	自動車部品	適用外	ラミネートガラスくず	160	有
79	製紙関連	406	バイオマスボイラー灰	300	有
80	エンジニアリング関連	202	シリカ系廃触媒	30	有

81	エンジニアリング関連	202	アルミナ系廃触媒	30	有
82	半導体関連	204	金属汚泥（プレス後）	4	有
83	半導体関連	204	金属汚泥	4	有
84	自動車関連	421	研磨汚泥	5	有
85	自動車関連	406	焼却灰	20	有
86	自動車関連	416	ペイント汚泥	不明	有
87	飲料関連	適用外	排水処理汚泥	100	有
88	製鉄関連	204	水酸化金属汚泥	30	有
89	エネルギー関連	204	シリカ汚泥	20	有
90	半導体部品	204	研磨汚泥	4	有
91	半導体部品	204	金属汚泥	17	有
92	半導体部品	207	フッ酸汚泥	50	有
93	半導体部品	204	混合汚泥	90	有
94	食料品関連	適用外	炭酸カルシウム	900	有
95	食料品関連	204	バイオ汚泥	90	無
96	工業道具関連	321	ゴム汚泥（乾燥前）	80	有
97	工業道具関連	321	ゴム汚泥（乾燥後）	不明	有
98	エネルギー関連	204	排水処理スラッジ	100	有
99	一般消費財	204	バイオスラッジ（乾燥前）	25	有
100	一般消費財	204	ケミカルスラッジ	20	有
101	一般消費財	104	五酸化バナジウム触媒（シリカゲル）	5	無
102	電子部品	204	Ni 汚泥	5	無
103	電子部品	204	研磨汚泥	60	無
104	化学関連	202	廃触媒	150	有
105	食料品関連	204	排水処理汚泥	10	有
106	食料品関連	202	廃触媒スラッジ	10	無
107	食料品関連	204	スカム	60	有
108	食料品関連	適用外	廃白土	200	有
109	化学関連	204	排水処理スラッジ	12	無
110	化学関連	204	水酸化アルミスラッジ	30	有

② セメントメーカーのニーズ等調査

マレーシア国内の大手セメント 4 社と継続的に、また新規で新たに参入を開始したセメント会社 1 社と協議を実施した。各社とも廃棄物、副産物受入の実績はあるものの廃棄物利用に関する経験、知見が少ないため、本事業には 5 社とも強い関心と興味を示している。実際に現地で取得した廃棄物のサンプル結果を基に ARM 製品のシミュレーションを行った結果、成分、数量共にセメント 5 社共に受入に問題がない結果となった。一方、昨年、マレーシア天然資源環境省（Ministry of Natural Rescores and the Environment）環境局（Department of Environment：以下、DOE と記す。）が中心となり、セメント各社、セメント協会との協議を通じて”Guideline on Environmentally Sound Co-Processing of Scheduled Wastes in Cement Industry in Malaysia”（「マレーシアのセメント産業における指定廃棄物利用に関するガイドライン」）を新たに策定し、セメント会社での受入可能な廃棄物の成分規格（Waste Acceptance

Criteria：以下、WAC）が明記された。現在は、新ガイドラインの WAC に沿って、各セメント会社との受入協議を進めている。本業務で取得した廃棄物サンプルを使用した製品シミュレーションの結果、協議している全てのセメント会社での受入は可能との回答を得ている。又、受入数量についても、本事業で予定している製造数量の受入についても問題ない旨、回答を得ており、既に一部のセメント会社とは具体的な契約の条件詰めを行っている。本事業で製造する ARM はマレーシアの指定廃棄物に関する環境規則（1989 年制定、2005 年に改定）上で SW421（A mixture of scheduled wastes.）に分類されるため、セメント各社は ARM を受け入れる際には DOE から EIA と SW421 の廃棄物受入ライセンスを取得する必要がある。こちらについても、既に一部のセメント会社が上記取得に向けて DOE との協議を進めている。

表 3.1.(2) セメント会社の廃棄物受入規格

No.	Parameter	Specifications (in dry basis)
1	SiO_2 (%)	Total of 2 major oxides should be >30% No specification in AF
2	Fe_2O_2 (%)	
3	Al_2O_3 (%)	
4	CaO (%)	
5	Cl (ppm)	Maximum 2%. Waste with total halogenated organic with > 1% Must be only used at the main burner
6	Moisture content (%)	≤70 %
7	Pb (mg/kg)	Total heavy metals: ≤100,000 ppm in ARM ≤10,000 ppm in AF
8	Cr (mg/kg)	
9	As (mg/kg)	
10	Sn (mg/kg)	
11	Se (mg/kg)	
12	Ni (mg/kg)	
13	Te (mg/kg)	
14	Co (mg/kg)	
15	V (mg/kg)	
16	Sb (mg/kg)	
17	Mn (mg/kg)	
18	Zn (mg/kg)	< 30,000 ppm in total input: ARM

19	Cu (mg/kg)	< 30,000 ppm in total input: ARM	
24	Hg (mg/kg)	< 10 ppm	Total volatile metal: < 100 ppm
25	Tl (mg/kg)	-	
26	Cd (mg/kg)	-	
27	Total organic content	< 1% if ARM fed in cold part of the process	
28	Calorific heating value	< 500 kcal/kg (in dry basis) in AF	

（参照：DOE セメントガイドラインより作成）

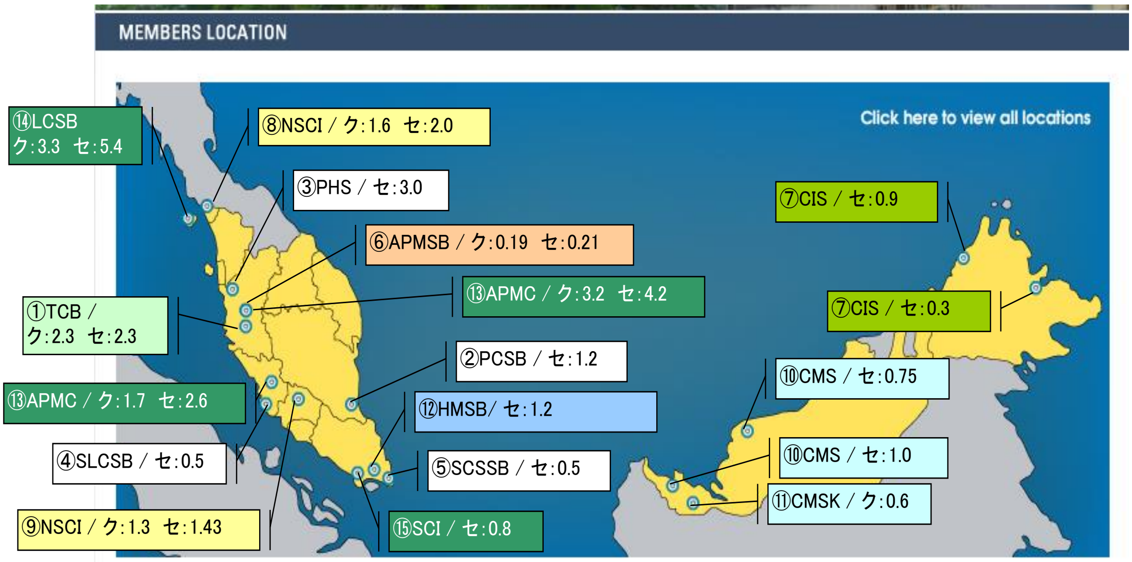


図 3.1.(1)　マレーシアのセメントマップ

（参照：マレーシアセメント協会 HP より作成）

表 3.1.(3)　マレーシアのセメント生産量

単位:百万トン/年						グループ合計	
グループ名	会社名	クリンカ	セメント	略称	No.	クリンカ	セメント
Tasek Corporation Berhad	Tasek Corporation Berhad (TCB)	2.3	2.3	TCB	①	2.3	2.3
YTL Cement Group	Pahang Cement Sdn Bhd (PCSB)	–	1.2	PCSB	②	–	1.2
	Perak-Hanjoong Simen Sdn Bhd (PHS)	–	3	PHS	③		
	Slag Cement Sdn Bhd (SLCSB)	–	0.5	SLCSB	④		
	Slag Cement (Southern) Sdn Bhd (SCSSB)	–	0.5	SCSSB	⑤		
Aalborg Portland Malaysia Sdn Bhd	Aalborg Portland Malaysia Sdn Bhd (APMSB)	0.19	0.21	APMSB	⑥	0.19	0.21
Cement Industries (Sabah) Sdn Bhd	Cement Industries (Sabah) Sdn Bhd (CIS)	–	1.2	CIS	⑦	–	1.2
CIMA Group of Companies	Cement Industries of Malaysia Berhad (CIMA)	–	–	CIMA	–	–	–
	Negeri Sembilan Cement Industries Sdn Bhd	1.6	2	NSCI	⑧	1.6	2
	Negeri Sembilan Cement Industries Sdn Bhd (Bahau Plant)	1.3	1.43	NSCI	⑨		
CMS Group	CMS Cement Sdn Bhd (CMS)	–	1.75	CMS	⑩	–	1.75
	CMS Clinker Sdn Bhd (CMSK)	0.6	–	CMSK	⑪		
Holcim (Malaysia) Sdn Bhd	Holcim (Malaysia) Sdn Bhd (HMSB)	–	1.2	HMSB	⑫	–	1.2
Lafarge Malayan Cement Berhad Group	Associated Pan Malaysia Cement Sdn Bhd (APMC)	4.9	6.8	APMC	⑬	4.9	6.8
	Lafarge Cement Sdn Bhd (LCSB)	3.3	5.4	LCSB	⑭		
	Southern Cement Industries Sdn Bhd (SCI)	–	0.8	SCI	⑮		

（参照：マレーシアセメント協会 HP より作成）

表 3.1.(3)　マレーシアのセメント工場数

EXISTING CEMENT FACTORIES IN MALAYSIA

STATES IN MALAYSIA	NUMBER OF CEMENT FACTORIES BASED ON THEIR PRODUCTS		TOTAL
	CEMENT	CLINKER / CLINKER & CEMENT	
Perak	0	5	5
Johor	2	1	3
Selangor	1	1	2
Sarawak	2	1	3
Negeri Sembilan	0	1	1
Pahang	0	1	1
Kedah	0	1	1
Perlis	0	1	1
Sabah	1	0	1
TOTAL			18

（参照：DOE 統計データ）

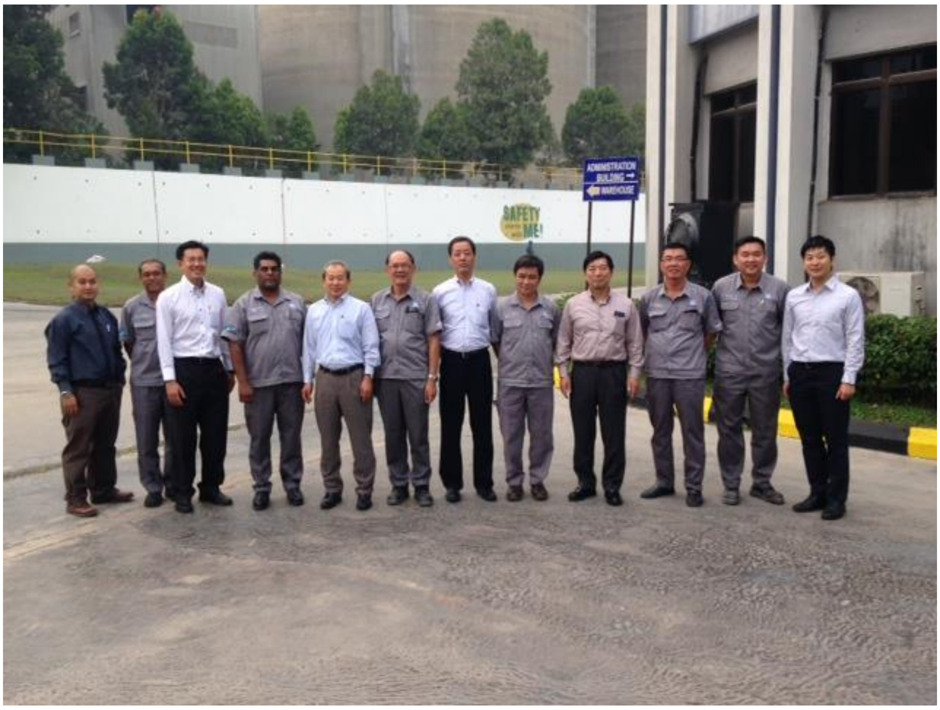


写真 3.1.(1)　マレーシアのセメント工場見学

③ 競合他社の動向調査

当該事業の優位性を確保するため、競合他社の最新動向やマーケット情報の調査を継続して実施した。調査方法は、主に排出事業者からの聞き取りと廃棄物処理会社からの聞き取りによるものである。KA 社以外の委託先には Thb Preference 社、World Wide 社、Shan Poornam Metals 社、Texcycle 社、Southern Strength 社、5E Resources 社、Positive Chemical 社などでいずれも液体系、固体系廃棄物のリサイクルを行っており、価格は KA 社と比較して 10～50%程度安価な処理費を設定している。実際に訪問した液体系廃棄物を扱う会社が有する廃液の処理能力は、3,000 トン/月（8 時間稼働）であったが、受入している数量は約 200 社から 500 トン/月程度であった。この会社では廃油や廃溶剤を間接加熱処理にて再生、販売を行っている。排出事業者から回収した廃棄物の 70～80%をリサイクルしており、残りの 20～30%（残渣等）は KA 社にて埋立処分している。その他、セメント大手の Lafarge 社、Tasek 社に直接廃棄物を委託している排出事業者も存在するが、こちらも処理費用は KA 社より安価であった。2015 年 2 月に KA 社と当該国政府間の独占契約が満了になったものの、現在も SW の唯一の焼却、埋立処理場であり、今後も動向を確認していく必要がある。一方、DOE としても従来の単純埋立、単純焼却処理から再資源化を促進、支援する方向性は打ち出されているため、市場は独占から開放に向かっていると思われる。又、廃棄物の運搬会社数社とも現地にて打合せを実施した。当該事業では数多くの日系企業が事業活動を行うペナン州やジョホールバル州の工業地域からも廃棄物を回収することを検討しており、セランゴール州で検討している再資源化工場までの距離は 400 ㎞以上に及ぶ。よって、廃棄物の収集運搬を実現するためにはこれらの陸送が可能な運送会社と連携することが必要不可欠である。一方、マレーシアで廃棄物の収集運搬を行う運送会社は多数存在するものの、収集可能な対象エリアが限られている会社や、所有するトラックが 2、3 台しかない会社が多いため、今後は長距離輸送が可能でかつ、所有トラックを多く持つ運送会社を見つけ、連携体制を構築することが重要である。

表 3.1.(4) SW ライセンス処理会社

No.	Lisence	Company
1)	Incinerator facilities for scheduled waste	30
2)	Off site storage facilities for scheduled waste	44
3)	Off-site treatment facilities for scheduled waste	6
4)	On-site treatment facilities for scheduled waste	1
5)	Secured landfill for scheduled waste	5
6)	Licensed transporters for scheduled waste	332
7)	Licensed off-site recovery facilities for scheduled waste	1000

特定廃棄物処理料金

Kualiti Alam Sdn. Bhd. は、マレーシア半島においてオフサイトの指定廃棄物処理サービスを提供している指定会社です。同社の廃棄物管理センターは、ネグリセンビラン州のブキットナナスにあります。指定外廃棄物の処理については、立地場所や委託業者によって収集料金および処理料金はさまざまです。

廃棄物グループ	廃棄物の種類
A	**廃棄鉱物油** 潤滑油や油圧用オイルなどを含んだ廃棄物。
B	**ハロゲンおよび/または硫黄＞1%を含む有機化合廃棄物** フレオン、*PVC*廃棄物、クロロホルム、溶剤、*PCB*を含むコンデンサーおよびトランスなど。
C	**ハロゲンおよび/または硫黄＜1%を含む廃棄物** アセトン、アルコール類(例 エタノール、メタノール)、ベンゼン、テレビン、キシレンなど。ポンプで汲み上げ可能で、50%以下の水分と18MJ/kg以下のカロリーを含む廃棄物。
H	**ハロゲンおよび/または硫黄＜1%を含む有機化学廃棄物** 接着剤、ラテックス、塗料、フェノール、印刷用インク、合成油、ソープ、エポキシなど。
K	**水銀を含む廃棄物** 水銀灯、*COD*液、水銀電池など。
T	**農薬廃棄物** 殺虫剤、殺菌および除草剤、殺鼠剤など。
X	**無機化学廃棄物** 酸、アルカリ、次亜塩素酸ナトリウム、無機塩類、金属水酸化物スラッジ、クロム酸塩、シアン廃棄物など。
Z	**その他** 医療廃棄物、ラボで使用した容器、アスベスト廃棄物、鉱物スラッジ、イソシアン塩酸(*MDI*、*TDI*)、電池など。

有機廃棄物の焼却処理

廃棄物グループ	パック済み廃棄物*				バルクの廃棄物			
	ポンプ汲み上げ可能な液体		個体		ポンプ汲み上げ可能な液体		個体	
	1トン当り / 1パレット当り				1トン当り / 1パレット当り			
	RM	¥	RM	¥	RM	¥	RM	¥
A	810	25,272	-	-	630	19,656	-	-
B	3,150	98,280	3,600	112,320	-	-	-	-
C	1,350	42,120	-	-	-	-	-	-
H/Z	1,890	58,968	2,790	87,048	1,800	56,160	2,700	84,240
T	3,150	98,280	3,600	112,320	-	-	-	-

TENORM(技術的に濃度が高められた自然発生の放射性物質)廃棄物の焼却

廃棄物グループ	パック済み廃棄物* 1トン当り / 1パレット当り		バルクの廃棄物 1トン当り / 1パレット当り	
	RM	¥	RM	¥
Z	4000	124,800	該当なし	

表 3.1.(5)　KA 社の処理費用

液体無機廃棄物の物理的/化学的処理

廃棄物グループ	800リットルのパレットタンク 1トン当り / 1パレット当り		200リットルのドラム缶 1トン当り / 1パレット当り	
	RM	¥	RM	¥
クロム塩酸を含まない酸化廃棄物(X)	1,440	44,928	1,620	50,544
シアンを含まないアルカリ廃棄物(X)	1,440	44,928	1,620	50,544
クロム塩酸廃棄物(X)	1,800	56,160	1,980	61,776
シアン廃棄物(X)	1,800	56,160	1,980	61,776
水銀廃棄物(K)	3,600	112,320	3,780	117,936

無機廃棄物の固形化処理

廃棄物グループ	パック済み廃棄物* 1トン当り / 1パレット当り		バルクの廃棄物 1トン当り / 1パレット当り	
	RM	¥	RM	¥
X / Z	810	25,272	765	23,868

*注：パック済廃棄物とは、通常の200リットルドラム缶あるいは 1 ㎥のPP袋に詰められた廃棄物。

無機廃棄物の直接埋立処理

廃棄物グループ	パック済み廃棄物* 1トン当り / 1パレット当り		バルクの廃棄物 1トン当り / 1パレット当り	
	RM	¥	RM	¥
X / Y	495	15,444	450	14,040

ゴムスラッジ廃棄物のゴムスラッジ埋立処理

廃棄物グループ	パック済み廃棄物* 1トン当り / 1パレット当り		バルクの廃棄物 1トン当り / 1パレット当り	
	RM	¥	RM	¥
X	700	21,840	該当なし	

封止処理

廃棄物グループ (Z)	パック済み廃棄物* 1トン当り / 1パレット当り	
	RM	¥
汚染された粉砕済ドラム缶および その他汚染廃棄物	1,500	46,800

セメント結合

廃棄物グループ (Z)	パック済み廃棄物* 1トン当り / 1パレット当り	
	RM	¥
乾電池およびその他廃棄物	900	28,080

*注：パック済廃棄物とは、通常の200リットルドラム缶あるいは 1 ㎥のPP袋に詰められた廃棄物。

廃棄物輸送費

KM	州	1パレット当り (RM)				1メートルトン当り	
		1段目の積荷 最低 18パレット		2段目の積荷 18パレット以上			
		RM	¥	RM	¥	RM	¥
114	ネグリセンビラン	52.88	1,650	26.44	825	66.10	2,062
248	クアラルンプール (連邦直轄地)	59.73	1,864	29.87	932	74.66	2,329
274	マラッカ	60.71	1,894	30.36	947	75.89	2,368
374	セランゴール	65.61	2,047	32.80	1,023	82.01	2,559
652	ペラ	79.32	2,475	39.66	1,237	99.14	3,093
722	ジョホール	82.25	2,566	41.13	1,283	102.82	3,208
760	パハン	84.21	2,627	42.11	1,314	105.26	3,284
1050	ペナン	113.59	3,544	56.79	1,772	141.98	4,430
1152	トレンガヌ	180.17	5,621	90.09	2,811	225.22	7,027
1166	ケダ	181.15	5,652	90.58	2,826	226.44	7,065
	ケダ (クリム)	142.24	4,438	71.12	2,219	177.80	5,547
1190	ケランタン	183.11	5,713	91.56	2,857	228.89	7,141
1240	ペルリス	184.09	5,744	92.04	2,872	230.11	7,179

注：パレットに積まれた廃棄物の場合、料金の見積もりは2段階となっています。1段目の積荷は最低18パレットで、2段目の積荷は、同一積荷における18パレット以上で、上限はありません。

資料出所: *Kualiti Alam Shd. Bhd. - www.kualitialam.com*

（参照：マレーシアセメント投資開発庁）

④　許可取得に関する調査

本事業の実現にあたっては、DOE 局長からの廃棄物処理ライセンスの取得が必要である。"Environmental Quality (Prescribed Premises) (Scheduled Wastes Treatment and Disposal Facilities) Order, 1989"によると、SW の取扱いができる施設が下記 6 種類に分類されている。

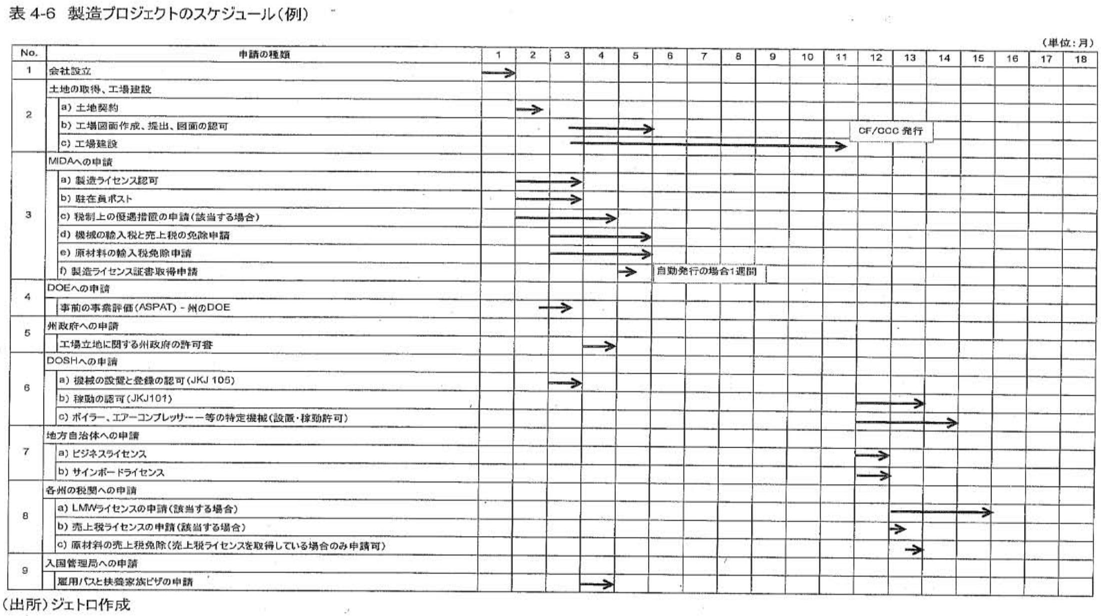
表 3.1.(6)　SW のライセンス区分（特定施設）

(1)	off-site storage facilities　（オフサイト保管）
(2)	off-site treatment facilities（オフサイト処理）
(3)	off-site recovery facilities（オフサイト回収）
(4)	scheduled waste incinerators　（SW 焼却炉）
(5)	land treatment facilities　（土壌処理）
(6)	secure landfills　（安全な埋立）

前述の通り、マレー半島における(2)off-site treatment facilities の許可は、KA 社のみが保有しているが、その主な処分方法は埋立、焼却である。現状、製造業の工場から発生する廃棄物の多くがこの KA 社にて処分されている。工場発生の廃棄物以外にも、(3)off-site recovery 許可取得事業者から排出される二次残渣の廃棄物がある。これらの残渣は KA 社での処理が義務付けられているため、再利用・再資源化可能な廃棄物も有効利用されていない。又、マレーシアには日本の「中間処理」に相当する概念や許可が存在せず、法律上も明確な規定がない。この点が本事業を進める上で困難な障害であり何度も DOE と協議を重ねてきた。DOE からは Preminally Site Assecment[1]（以下、PAT と記す。）の提出を求められ、2014 年 12 月に DOE セランゴールに対して PAT を提出。PAT 提出に当たっては現地の環境コンサルタントを通じて実施した。提出後、DOE セランゴール、DOE 本部の担当者と数回に渡る打合せを実施し、2015 年 1 月に正式に PAT が受理された。当初、Off-site recovery もしくは Off-site treatment の処理ライセンスの取得を見込んでいたが、DOE 本部、DOE セランゴール州の担当者と協議する中で、当該事業は Off-site Storage に該当するとの見解に至った。その後、Environment Impact Assessment（以下、EIA 提出と記す。）を 2015 年 10 月に提出し、DOE 側と何度か協議を重ね 2015 年 12 月に EIA も承認された。現在は、Environmental Management Plan（以下、EMP 提出と記す。）の提出を準備しており、今後は Off-site Storage、Transportation のライランス取得に向けて準備を進める。

[1] http://www.ssic.com.my/Appendix_2_AS_PAT_1_12_Form.pdf

表 3.1.(7)　製造プロジェクトの許認可スケジュール（JETRO 作成）



（出所）ジェトロ作成

4. 現地政府・企業等との連携構築

上述の通り、許認可の取得を進めるためDOE本部、DOEセランゴール、土地管理局（Federal Lands Commissioner：以下、FLC）、住宅自治省（Kementerian Perumahan dan Kerajaan Tempatan：以下、KPKT）等と現地パートナー、環境コンサルティング会社を協議を行った。又、2015 年 5 月 26、27 日マラッカで行われた DOE 主催の‘’Special Waste Management and Sharing Session of Success Story”のセミナーに参加し、DOE、セメント会社、排出事業者等との関係構築を行った。尚、当日のセミナー資料は巻末付属資料として添付する。

日時	2015 年 5 月 26 日(火)
セミナー名	Special Waste Management and Sharing Session of Success Story
会場	A Formosa Resort and Hotel
出席者	アミタ㈱大和
内容	・Direction and SW Management 2015 and Environment Quality Act (Scheduled Waste) について Ms. Norhazni Mat Sari (Director)より発表あり。 ・Special Waste Management について Mr. Rosli Zul より発表あり。 ・Success Story 1 - Co-processing について Lafarge Cement の Mr. Pavel より発表あり。廃棄物利用を始めた 2003 年に 4,000 トンだった取扱量が 2015 年は 400,000 トンを見込んでいる。持っている SW コードは SW104、204、205、206、207、313、320。今後のターゲットは Contaminated Soil、建設系廃棄物、

	賞味期限切れの商品を狙っている。台湾からジョホールバル州に輸入された廃棄物 6,000 トンが 10 年間放置されていたが、DOE の要請を受けて処理を実施した。現在の試算では、利用した廃棄物の効果は、1,500 トンの天然資源の削減、100 トンの CO2 削減、4,000 トンの埋立廃棄物削減である。 ・Success Story 2 - Study on Green Brick について Tioxide の Mr. Teryy より発表あり。UMP（マレーシアプトラ大学）と共同で研究し排水処理汚泥から G-Brick を製造。Cement Brick とほぼ同等の質を実現。今後は UMP での建設工事でも使用していく。 ・Success Story 3 - Ceramic Production について White Horse の Ms. Lim より発表あり。2014 年に 33,512 トン発生した排水処理汚泥の 33,362 トンを活用して自社のセラミック製品を製造した。

日時	2015 年 5 月 27 日(水)
セミナー名	Special Waste Management and Sharing Session of Success Story
会場	A Formosa Resort and Hotel
出席者	アミタ㈱大和
内容	・Environment Quality Act (Clean Air) について、Mr. Cik Nor Rashidah Ghazali より発表あり。 ・Code Practice for Labelling of SW について、Ms. En. Nurmizhuari Abd Samad より発表あり。 Management of Contaminated Soil について、Ms. Ijan Khushaida より発表あり。Contaminated Soil（SW408）の管理についての法律、罰則等の説明。今後セメント会社での活用が期待される。

日時	2015 年 11 月 6 日(金)
訪問先	DOE 本部
会議場所	Putra Jaya
出席者	DOE 本部、DOE セランゴール州、KPKT、環境コンサル会社、建設コンサル会社、現地パートナー、アミタ社
目的	EIA Panel Meeting （EIA 提出後の説明会）

写真 4.1.(1)　DOE との協議の様子

2015 年 6 月中旬にはセメント社がセメント代替原料を製造する当社、姫路及び北九州循環資源製造所、製造したセメント代替原料を納める近隣のセメント会社を見学。事業への理解と関係構築を行った。

日時	2015 年 6 月 17 日(水)～18 日（木）
訪問先	アミタ㈱姫路循環資源製造所 アミタ㈱北九州循環資源製造所 宇部興産㈱苅田工場
出席者	マレーシアセメント会社、アミタ㈱
目的	セメント産業における廃棄物利用の取り組みの研修

写真 4.1.(2)　アミタ㈱姫路製造所を見学

写真 4.1.(3)　宇部興産㈱苅田工場を見学

日時	2015 年 10 月 20 日(火)
訪問先	アミタ㈱茨城循環資源製造所 茨城県内の廃棄物運送会社
出席者	マレーシア廃棄物運送会社、アミタ㈱
目的	セメント産業における廃棄物利用の取り組みの研修 セメント代替原燃料の荷卸し方法、輸送方法についての確認

写真 4.1.(4)　アミタ㈱茨城循環資源製造所を見学

5.　現地関係者合同ワークショップ等の開催

当初予定していたマレーシアでの現地ワークショップは、DOE との調整がつかなかったため、開催は延期になったが、本事業に対するマレーシア DOE の理解をより一層深めるため、日本環境衛生センター（以下、JESC）が実施する「平成 27 年度我が国循環産業海外展開事業化促進のための研修」の日程に合わせ、新たに就任した DOE 新局長含め 3 名の DOE 関係者を日本に招聘しワークショップを開催した。1 日目、2 日目は日本の廃棄物管理の概要、産業廃棄物、有害廃棄物の処理、リサイクル方法について学んだ。又、セメント協会にご協力を頂き日本のセメントリサイクルの取組みについても講義を頂いた。3 日目、4 日目は北九州に移動して、北九州市による廃棄物行政、エコタウン事業の説明、アミタ北九州循環資源製造所見学、セメント会社見学を実施した。5 日目は研修プログラムの振り返りを実施するとともに、日本の環境省、マレーシアの環境省より廃棄物行政についての発表を相互に行った。本ワークショップを通してマレーシア側のセメントリサイクルに対する理解の促進と新局長との関係構築を図ることができ非常に有意義なワークショップ開催となった。

日時	2016 年 2 月 29 日(月)～3 月 4 日(金)
訪問先	下記、表 5.1.(1)招聘スケジュールを参照
参加者	DOE3 名　(DOE 本部局長、DOE セランゴール州局長、DOE 担当官) 現地パートナー2 名、アミタより 3 名
目的	DOE への事業理解の促進と関係構築

表 5.1.(1)　招聘スケジュール

月日	時刻	内容	場所
2016年2月28日（日）	15:50　成田着	マレーシアより到着	川崎
2016年2月29日（月）	終日	【講義】 プログラムオリエンテーション 日本の廃棄物管理法の概要 日本のリサイクル技術 日本における廃棄物のセメントリサイクル　など セメント協会様による講義	川崎
2016年3月1日（火）	終日	【工場見学】 e-Wasteリサイクル工場見学 建設廃棄物リサイクル工場見学	川崎
2016年3月2日（水）	午前	【講義】 北九州市役所本庁舎	北九州
		昼食	
	午後	【講義】 北九州エコタウンセンター	
	午後	【工場見学】 アミタ株式会社　北九州循環資源製造所	
2016年3月3日（木）	午前	【工場見学】 宇部興産 宇部セメント工場	北九州
		昼食	
	午後	東京へ移動	
2016年3月4日(金)	終日	研修プログラム振り返り 環境省、DOEとのディスカッション 全体クロージング	川崎

写真 5.1.(1)　研修初日の様子

写真 5.1.(2)　建設廃棄物リサイクル工場見学

写真 5.1.(3)　e-waste リサイクル工場見学

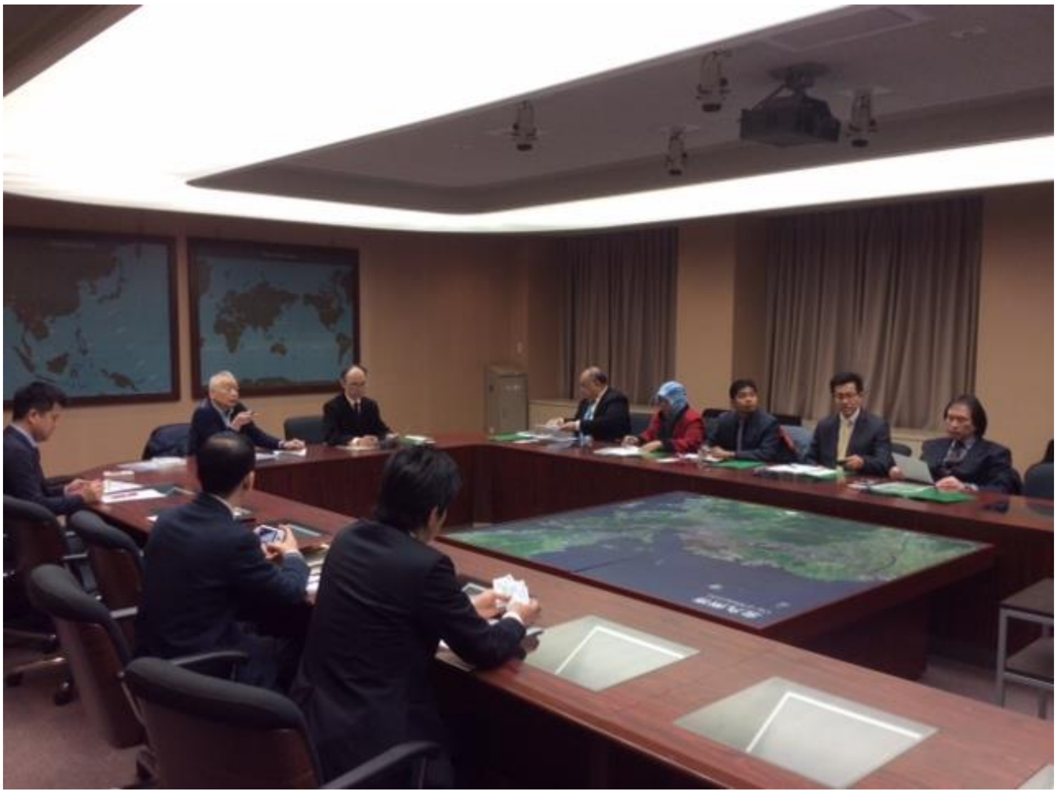


写真 5.1.(4)　北九州市庁舎で廃棄物行政の説明

写真 5.1.(5)　北九州エコタウンの説明

写真 5.1.(6)　北九州エコタウンセンターにて

写真 5.1.(7)　 アミタ㈱北九州循環資源製造所の工場見学

写真 5.1.(8)　 アミタ㈱北九州循環資源製造所にて

写真 5.1.(9)　宇部興産㈱宇部工場にて

写真 5.1.(10)　宇部興産㈱宇部工場にて

写真 5.1.(11)　研修最終日の様子

6. 実現可能性の評価

6.1 事業採算性

現時点の FS では、5 年以内に投資回収が可能である。今後の事業実現のポイントと課題は下記の 5 点である。

①工場建設にかかる初期投資コストの精査
土木工事、建設工事にかかる初期投資コストの最小化を現地パートナーと協力して進める。

②製造設備と据付、電気工事の現地調達化
主要製品は日本から輸出するが、製缶品等現地で調達できるものについては、極力現地での製造を目指す。又、工場稼働後のメンテナンスやアフターサービスの必要性を考え、据付工事、電気工事についても、極力現地化を進める。

③処理費の価格設定
廃棄物分析についても全て現地でできるように分析機器の選定を行う。又、分析後の成分を用い ARM 製造の混合シミュレーションを行い、現地で発生する製造原価を算出した後、処理の価格設定を進める。

④廃棄物運送会社の協議
排出事業者から当該事業場までの運搬ができる運送会社の選定、そして、運搬方法、運搬費、

発注形態の協議、交渉を進める。

⑤セメント会社との協議

ARM を配給する際に発生する処理費の協議。分析に係る費用負担の方法。又、当該事業場からセメント会社まで運搬ができる運送会社の選定、そして、運搬方法、運搬費、発注形態の協議、交渉を進める。

上記 5 点を順次進めながら事業 FS のさらなる精査を行う。

6.2 環境負荷削減効果

①単純焼却処理、単純埋立処理から 100%再資源化へ

DOE 作成資料（2014 年 12 月）によると、2013 年に確認された SW 発生量は、約 296 万トンである。その内訳は以下の通りである。尚、2014 年以降の統計データについても、DOE に確認したが、DOE の統計データの公表は数年に一度行われており、2014 年度のデータは製作中で 2016 年 5 月以降に回答予定とのことであった。

表 6.2.(1)　SW の発生量データ（処理方法別の数量）

処理方法	処理量	処理割合
許可取得済みの特定施設で処理	約 157 万トン	53.08%
排出事業者の工場内で処理	約 63 万トン	21.25%
国内の回収業者で処理	約 56 万トン	19.1%
KA 社で処理	約 11 万トン	3.77%
排出事業者で保管	約 4 万トン	1.41%
Trienekens（サラワク）社で処理	約 1.9 万トン	0.65%
国内の医療廃棄物焼却炉で処理	約 1.8 万トン	0.61%
国外に搬出され処理	約 3,700 トン	0.13%
合計	約 296 万トン	100%

（参照：DOE 統計データより）

下記、図 2.5.(3)は SW の処理方法をまとめたデータであり、焼却処理が 49%、埋立処理が 47%、固形化処理が 10%、化学処理が 3%と全体の 90%以上が焼却、埋立にて処分されていることが分かる。一方、本統計データの全てを合計すると 100%を超えるため、その点を DOE に確認したが、各州からの情報データに誤りや齟齬があり、DOE としても正確な数字の把握することが難しいとのことであった。本事業で再資源化できる可能性があるにも関わらず単純焼却、単純埋立されている廃棄物を回収し、水、熱、化学物質を一切使わない「混合処理」によって再資源化することで焼却、埋立時に生じる様々な環境負荷を低減することを目指している。不法投棄も増加傾向にあるが、調べた限りでは具体的な数字や件数は公表されていない。これまで重ねてきた排出事業者へのヒアリングを通し、廃棄物処理ルートの不透明さを事業リスクとして掲げる企業も多数存在した。本事業は、受け入れた廃棄物を ARM、AF として 100%再資源化し、セメント製造工場にて利活用することにより処理の透明性担保に寄与するものでもある。

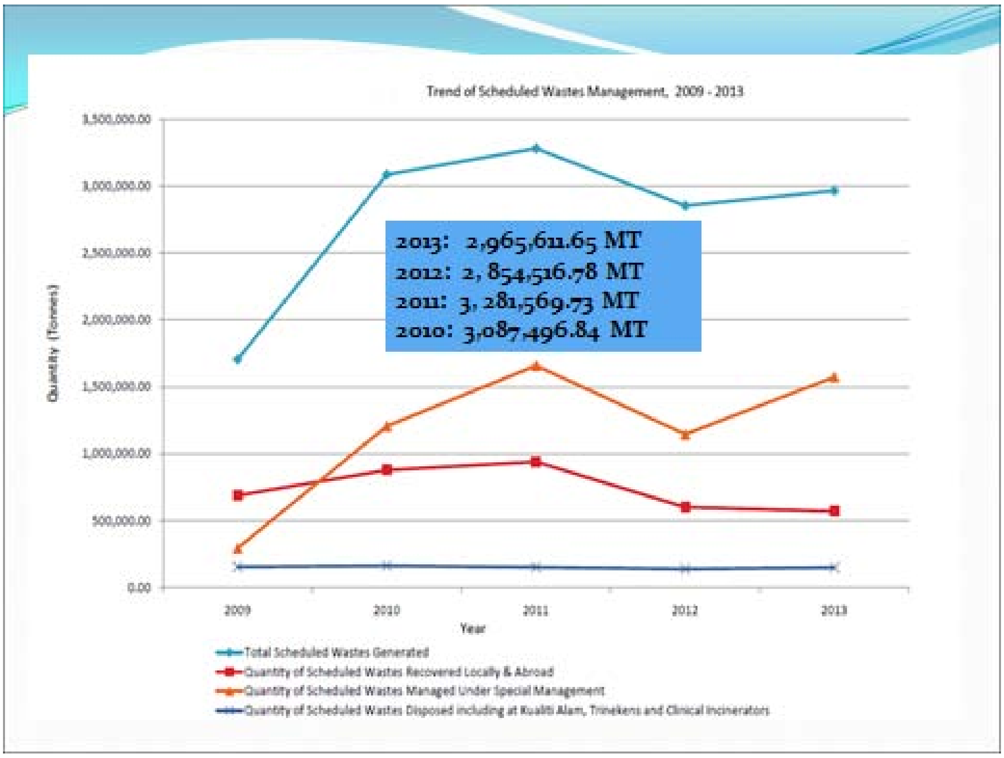


図 6.2.(1)　SW の発生量データ（年次推移）

（参照：DOE 統計データより）

Facilities Handling Scheduled Wastes in Malaysia – year 2013

No	Facility	Tonnes	Percentage (%)
1	Special Waste Management	1,574,041.95	53.08
2	On-Site Treatment	630,221.40	21.25
3	Local Off-site Recovery Facilities	566,506.51	19.10
4	Kualiti Alam Sdn Bhd	111,860.20	3.77
5	On-Site Storage	41,742.48	1.41
6	Trienekens (Sarawak) Sdn Bhd	19,330.00	0.65
7	Off-site Clinical Waste Incinerators	18,201.05	0.61
8	Foreign Facilities (Export)	3,708.07	0.13
	TOTAL	**2,965,611.65**	**100.00**

図 6.2.(2)　SW の処理先一覧（2013 年版）

（参照：DOE 統計データより）

図 6.2.(3)　SW の処理方法（2013 年版）
（参照：DOE 統計データより）

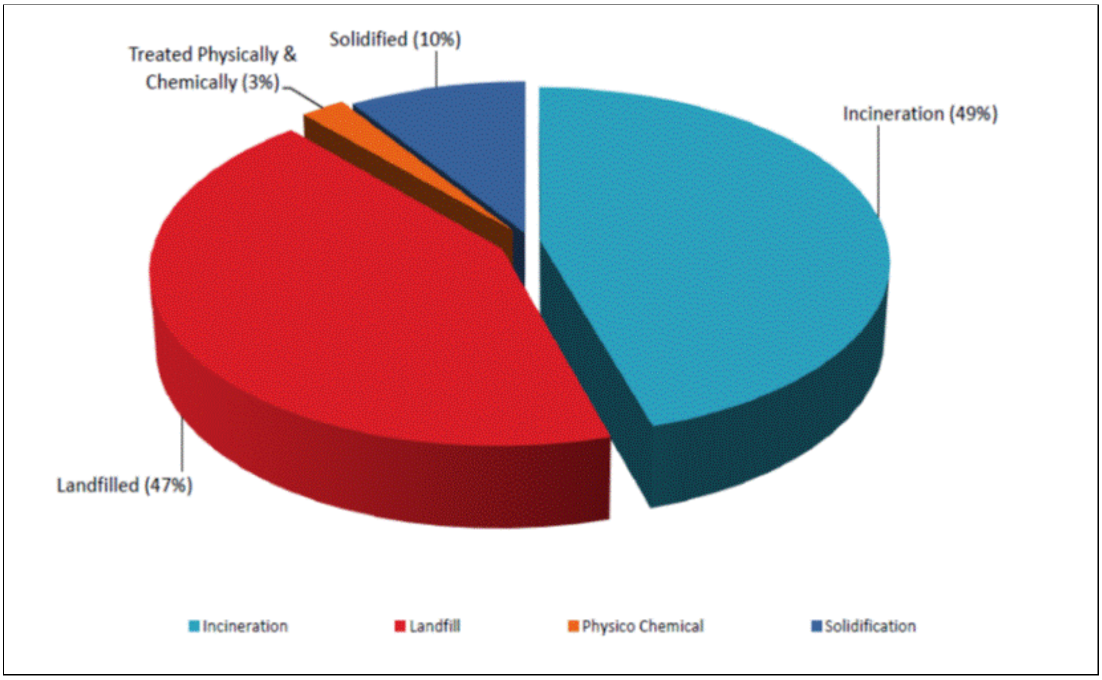


図 6.2.(4)　SW の処理方法（2013 年版）
（参照：DOE 統計データより）

②天然資源の使用量削減

セメントの原料は、石灰石、粘土、けい石、酸化鉄原料、石膏に分類され、セメント1トン(1,000kg)の製造に必要な原料は、おおよそ石灰石 1,100kg、粘土 200kg、その他原料 100〜200kg である。マレーシアのセメント生産量は年間 2,000 万トン程度なので、これら全てを天然資源で製造した場合に必要な資源の使用量は、石灰石が 2,200 万トン、粘土が 400 万トン、その他原料が 200〜400 万トンである。本事業は、製造工程から発生する多量多品種の廃棄物･副産物、又、将来的には off-site recovery 事業者から排出される二次残渣を ARM、AF として使用することで、天然資源の使用量削減に寄与することが可能である。

③最終処分場の延命化

現状埋立処分をされている廃棄物や副産物、二次残渣をセメント原料化することにより、本来必要とされる最終処分場の容積を減らすことに繋がり､最終処分場の延命化に貢献することとなる。実際我が国では、2012 年度にセメント産業が約 2,850 万 t/年の廃棄物・副産物を受け入れ､最終処分場が 8 年延命されたと試算されており､セメント産業での受入量増加により環境負荷低減面での貢献が大きいことが報告されている｡また最終処分場の延命化により､発生するメタンガスの排出量削減､ひいては温室効果ガス排出量の削減につながると同時に、最終処分場周辺環境への負荷低減にも寄与するものである。又、マレーシアには 150 を超える最終処分場があると言われているが、周辺の環境を汚染しない｢衛生埋立処分場｣は非常に少なく､周辺環境への影響が懸念されている｡又､閉鎖した処分場についても、不適切な跡地利用が行われた結果､河川汚染などの深刻な環境問題が発生した事例も報告されているため､埋立からリサイクルの流れを推進していくことでマレーシアの環境負荷が軽減される。

③温室効果ガス排出削減効果

当該事業によって廃棄物から製造された ARM、AF をセメント会社で活用した場合に想定される温室効果ガス排出の削減効果の考え方は、（1.セメント工場での石炭代替分）＋（2.単純焼却代替分）＋（3.埋立処分場からのメタン発生）－（4.再資源化工場での電力・燃料消費）＋（5.輸送距離低減分）になるが、回収する複数の廃棄物中に含まれる組成と熱量が異なる点、単純焼却、単純埋立処理の過程で発生する温室効果ガスを算定できなかった点、又､セメント向けの代替原燃料の扱いについて国際的に共通化された手法が確立されていない等の理由から､現時点で明確な温室効果ガス削減効果が検証できないため､本項目は今後の課題として引き続き検証、検討を行う。

④循環型社会形成への寄与

マレーシアには中間処理という概念がなく、民間のリサイクル会社で発生する処理後の残渣物は全て、KA 社で埋立、焼却処理が行われている。当該事業の許可が取得できれば、中間処理の認知と理解が広がり､単純埋立、単純焼却処理の削減と処理後に発生する残渣物の再資源化も可能となる。また資源循環網が構築され､市場での競争が発生することで健全なリサイクル市場の確立につながり､ひいてはマレーシア国での循環型社会形成に寄与すると確信する。

6.3 社会的受容性

【廃棄物のリサイクル方針】

マレーシア政府は、2020 年までに先進国入りすることを目指した中期計画である「WAWASAN2020」において、廃棄物のリサイクル率を 22%まで向上させる目標を明確に打ち出している。また、2001 年に制定された"The Third Outline Perspective Plan (2001-2010)"では、ゼロ・エミッション技術の利用を促進し、エネルギー消費の削減や、廃棄物再利用および再生方針が打ち出されている。さらに、第 10 次マレーシア計画（2011-2015）においては、再生不可能な資源の持続的マネジメント、グリーン技術の生産・加工工程への導入が戦略の一つとして明記されている。マレーシア政府が循環型社会の実現を重要視していることは、上記の各方針が打ち出されていることから明らかであり、当該事業がこれら方針に合致し、社会的受容性を十分に有すると確信する。また前述の通り、2015 年 2 月に期限切れとなった KA 社との契約についても、今後も事業は続けられる見通しだが、独占的な契約は見直され、廃棄物市場が民間にも広く開放されるという見通しが強い。

【DOE の姿勢】

近年、DOE によって承認される off-site recovery（回収）ライセンスを受ける事業者は増加傾向にある。このことからもマレーシア国の廃棄物関連当局はリサイクル促進の必要性、並びに適正な競争と静脈産業の育成を促進しつつあると考えられる。本事業によるセメント代替原料、燃料製造事業はマレーシアにとっても初めてのケースであり、2015 年 12 月には申請した環境アセスメントも無事承認されたこともあり、DOE からの期待も非常に大きい。廃棄物処理ライセンスの許認可取得は 2016 年夏頃を予定している。

【セメントリサイクルの促進】

前述の通り、2015 年 5 月に「セメント産業における廃棄物利用に関するガイドライン」が策定され、今後ますますセメントリサイクルが普及していく見通しである。一方、既に廃棄物を受け入れしている 2 社を除き、他のセメントメーカーは廃棄物利用の経験が乏しく、当該プロジェクトにおける当社また日本の環境省からのさらなる支援について、セメント各社からの期待も大きい。

【日系企業のニーズ】

当該調査を実施する前からの訪問先も含めると既に 120 社近くの日系企業（一部現地企業）を訪問し、既に複数の企業からサポートレターを受領している。これらの企業は CSR 活動の一環として海外事業所を含めたゼロ・エミッション目標を掲げており、また廃棄物処理の透明性確保を重視している企業である。当該事業がリサイクル率向上および廃棄物処理の透明性向上に寄与する期待は非常に大きい。当初予定していたマレーシアでの現地ワークショップは、DOE との調整がつかなかったため開催は延期になったが、2016 年度に開催を実現し、継続して現地日系企業のニーズのヒアリングを実施する。

6.4 実現可能性の評価

当該事業の実現においては、主に①排出事業者のニーズ②セメント会社のニーズ③競合他

社の動向④許可取得の 4 つの要因分析が必要である。

①排出事業者のニーズ
上述の通り、再資源化のニーズは非常に高く、特に日系企業を中心とした外資系企業からの再資源化、不適正処理に巻き込まれないための対策に関する要望は強い。また、近年ではローカル企業のコンプライアンス意識も向上しており、リサイクル率を掲げて再資源化を進める企業が増えてきている。今後は、排出事業者を集めた廃棄物リスク、法令に関するセミナーを現地で開催しより一層のニーズ調査を進めていく。

②セメント会社のニーズ
これまでに取得した廃棄物サンプル分析結果に基づく製品シミュレーションとサンプル提供によるセメント会社の判断では、セメント会社が有する受け入れ基準に概ね合致することが確認された。新たに「セメント産業における廃棄物利用に関するガイドライン」も策定され、今後セメントリサイクルの需要はさらに高まることが予想される。

③競合他社の動向
KA 社よりも安価な処理費で廃棄物を回収、処理をしている業者がいくつか存在する。当該事業の優位性確保のため、引き続き競合他社の最新動向を調査する。2015 年 2 月に契約満了になった KA 社と当該国政府間の独占契約の今後の動向や近年増加傾向の off-site recovery 許可取得事業者の最新動向を引き続き調査する。

④許可取得
当該事業の実現は、当該国当局からの許可取得にかかっている。環境コンサルティング会社と契約し、2015 年 12 月には DOE から EIA の承認を獲得。今後は EMP の申請、処理業、運搬業の許認可申請を進める。当該事業に対するマレーシア国関係機関の理解を更に深めるために効果的な説明会や啓蒙活動を継続的に実施していく。また、頻繁に行われる法規制の変更に対応すべく、逐次情報の収集・整理を遂行する。

7. 今後の海外展開計画案

今後の事業化に向けたスケジュールは下記に示す表 7.1.(1)を予定している。前述の通り、循環型社会システム構築へ向けたマレーシア当局の方針は明確であり、本事業もその方向性に合致している旨の見解を当該国当局より得ている。本事業は今までマレーシアには無かった初めての事業モデルであり、本事業に関係する複数の行政機関への説明や見解の調整に時間がかかっている点など解決すべき課題もまだ多いが、引き続き日本行政の支援を得ながら本事業の早期実現を粘り強く目指すと共に、環境省が掲げる「我が国が有する循環産業の海外展開の促進」を通じて、本事業を早期に実現させマレーシアのさらなる発展とセメント産業を活用した循環型社会構築の実現に寄与していきたい。

表 7.1.(1)　事業化スケジュール

	2016 1月	2月	3月	4月	5月	6月	7月	8月	9月	10月	11月	12月
許認可申請関連												
各種許認可申請		EMP申請				処理・運搬業申請					建物使用・設備設置許可申請	稼働（予定）
工事関連												
工場建設			土木工事		建屋工事						完成	
設備関連			発注					輸送		据付	完成	

尚、工場第一期から第三期までの予定は下記の通りである。

工場第一期（2017 年予定）：　混合機、磁選機、振動ふるい機導入
工場第二期（2020 年予定）：　破砕機、粉砕機導入
工場第三期（2023 年予定）：　高含水受入ライン、紛体物受入ライン導入

以上

巻末付属資料 1

マレーシア

「環境保全（指定廃棄物）規則 2005」

PU (A) 249/ 2005（日本語版）

（2005 年 8 月 15 日施行）

環境保全（指定廃棄物）規則 2005
Environmental Quality (Scheduled Wastes) Regulations 2005
PU (A) 294/ 2005

2005 年 8 月 15 日
Jil. 49,; No. 16,; 15 August 2005,; Tambahan No. 74 Perundangan (A)

環境保全法 1974 [法 127 号] 第 21 条及び第 51 条によって付与された権限に則り、(天然資源環境) 大臣は、環境保全委員会（Environment Quality Council）との協議を経て、以下の規制を策定する。

1. 名称及び施行

(1) これらの規制は、環境保全（指定廃棄物）規則 2005 と名付けられる。

(2) これらの規則は、2005 年 8 月 15 日付を以って施行される。

2. 解釈

(1) これらの規則は、文脈上ほかの意味に解釈されない限り、

「指定廃棄物」とは、附則 1 に掲げられた廃棄物分類のいずれかに当たる廃棄物を意味する。

「混合できない指定廃棄物」とは、附則 4 で規定された指定廃棄物を指し、これらを混合した場合、発熱、発火、爆発または有害物質の放出といった形態で、危険な事態に至る廃棄物のことをいう。

「オンサイト処理施設」とは、指定廃棄物焼却炉または土壌処理施設以外で、廃棄物発生者サイトに立地し、当該サイトで発生する指定廃棄物を取り扱うためにのみ利用される施設を意味する。

「委託業者」とは、環境保全法 1974 第 18 条（1A）項の下、(天然資源環境省) 環境局長（Director General, Dept. of Environment）によって認可された全ての業者を指す。

「廃棄物発生者」とは、指定廃棄物を発生させる全ての者を指す。

「指定施設（prescribed premises)」とは、環境保全（指定施設）(指定廃棄物処理・処分施設）命令 1989 [P.U. (A) 140/1989]によって規定された施設を指す。

(2) これら規則で定義されていない用語と表現は、環境保全法 1974 及び環境保全（指定施設）(指定廃棄物処理・処分施設）命令 1989 によって規定された同じ意味が割り当てられる。

3. 指定廃棄物の発生に関する届出

(1) 全ての廃棄物発生者は、指定廃棄物の発生から 30 日以内に、新規に発生させた指定廃棄物の分類及び発生量を環境局長宛に届出なければならない。

(2) 上記 (1)項に基づく本届出は、附則 2 によって提供されている情報が盛り込まれていなければならない。

4. 指定廃棄物の処分

(1) 指定廃棄物は、指定施設のみで、処分されなければならない。

(2) 指定廃棄物は、実行可能な限りにおいて、処分前に無害化されなければならない。

5. 指定廃棄物の処理

(1) 指定廃棄物は、指定施設またはオンサイト処理施設に限定して、処理されなければならない。

(2) 指定廃棄物の処理の残さは、指定施設において、処理または処分される。

6. 指定廃棄物からの原材料あるいは製品のリカバリー

(1) 指定廃棄物からの原材料あるいは製品のリカバリーは、指定施設またはオンサイト処理施設において行われる。

(2) 指定廃棄物からの原材料あるいは製品のリカバリーから生じた残さは、指定施設におい

て処理または処分される。

7. 指定廃棄物の特別管理に関する申請

(1) 廃棄物発生者は、環境局長宛に書面で申請することにより、指定の設備（particular facility）あるいはプロセスから発生する指定廃棄物について、指定施設、オンサイト処理施設またはリカバリー施設以外の施設あるいは設備（facilities）において、処理、処分またはリカバリーされることの免除を受けることができる。

(2) 上記(1)項に基づく申請書は、環境局長の規定に則り、指定廃棄物の特別管理に関するガイドラインに従って、環境局長宛に提出されなければならない。なお、同申請に伴って、支払いが求められる 300 リンギットの手数料は、払い戻しされない。

(3) 上記(1)項に基づいて提出された申請書を環境局長が承諾した場合、環境局長は、書面により、条件付きまたは条件なしの許可を発給することができる。

8. 廃棄物発生者の責任

(1) 全ての廃棄物発生者は確実に、当人が発生させた指定廃棄物を適正に保管し、その指定廃棄物から得られる原材料または製品に関して、オンサイト処理ないしオンサイト・リカバリーを施すかまたは処理を施すための指定施設に運搬、納品し、指定廃棄物から得られる原材料、製品の処分またはリカバリーを図らねばならない。

(2) 全ての廃棄物発生者は、環境局長が規定したガイドラインに従って、移動または移送の対象となる指定廃棄物には、必ず包装、表示を施し、運搬しなくてはならない。

9. 指定廃棄物の保管

(1) 指定廃棄物は、指定廃棄物の保管に適し、耐久性があり、環境への指定廃棄物の流出や漏洩を防ぐことができる容器に保管されなければならない。

(2) 混合できない指定廃棄物は、必ず別々の容器で保管し、当該容器は、別々の 2 次格納エリアに納められなければならない。

(3) 指定廃棄物が入った容器は、指定廃棄物を加えるか、取り出す必要がある時以外は、常に密封しておかなければならない。

(4) 容器の保管エリアは、指定廃棄物の環境への流出、漏洩を防止するために、環境局長によって規定されたガイドラインに沿って、適正に設計、施工、維持されなければならない。

(5) いかなる者も、以下の条件を満たす限りにおいて、当人が発生させた指定廃棄物をその発生後 180 日以下の日数だけ保管することができる。

(a) オンサイトで蓄積される指定廃棄物量は、20 トンを超えてはならない。さらに、

(b) 環境局長は、いかなる時でも必要と考える分量だけ、廃棄物発生者に対して処理、処分またはその指定廃棄物から得られる原材料ないし製品のリカバリーを図るために、指定廃棄物の移送を指示することができる。

(6) 廃棄物発生者は、20 トンを超える指定廃棄物を保管することを環境局長宛に書面で申請することができる。

(7) もしも環境局長が、上記(6)項に基づき作成された申請書を承諾した場合、環境局長は、書面により、条件付きまたは条件なしの認可を発給することができる。

10. 指定廃棄物の表示

(1) 指定廃棄物を保管するために利用される容器には、当該指定廃棄物が最初に発生した日付、廃棄物発生者の氏名、住所、電話番号が明確に記載された表示が施されていなければならない。

(2) 指定廃棄物の容器は、識別と警告の目的のために、附則 3 で規定された廃棄物の種類に従って、明確に表示が施されていなければならず、また附則 1 で規定された指定廃棄物コードが付けられていなければならない。

(3) いかなる者も上記(1), (2)項で述べられているマークや表示を変更してはならない。

11. 廃棄物発生者による指定廃棄物の目録（インベントリー）の保管

廃棄物発生者は、附則 5 に則り、指定廃棄物が発生した日から 3 年間に至るまで、発生、処理、または処分した指定廃棄物、並びに当該指定廃棄物から得られた原材料または製品についての分類と量に関する正確で最新の目録を保管しておかなければならない。

12. 廃棄物発生者、委託業者及び指定施設の所有者が提出しなければならない情報

(1) 廃棄物発生者、委託業者及び指定施設の所有者は、附則 6 の方法に則り、本規則で規定されている情報を提供する。しかし、環境局長が妥当と判断して決定したその他の方法に従う場合もある。

(2) 廃棄物発生者は、附則 6 のパートⅠフォームを 6 部作成し、指定廃棄物を委託業者に引き渡す際に、附則の同コピー6 部を委託業者に渡さなければならない。

(3) 委託業者は、廃棄物発生者から指定廃棄物を引き取った際に、廃棄物発生者から渡されたコピー6 部の中の附則 6・パートⅡの部分を記載の上、直ちにコピー2 部を廃棄物発生者に送付しなければならない。次に廃棄物発生者は、指定廃棄物の運搬日から 30 日以内に、そのコピー1 部を環境局長宛に提出しなければならない。

(4) 委託業者は、指定廃棄物を引取ってから 10 日以内に、当該指定廃棄物を指定施設の所有者に引き渡し、附則 6 の残りのコピー4 部を当該施設の所有者に渡さなければならない。

(5) いかなる指定施設の所有者も、指定廃棄物を委託業者から引取った際には、委託業者から渡された附則 6 のコピー4 部のうちのパートⅢの部分を完成し、記入し終えたら、うち 1 部を自ら保管し、また指定廃棄物を引取ってから 20 日以内に、委託業者、廃棄物発生者及び環境局長宛にコピー各 1 部を返却しなければならない。

(6) 廃棄物発生者が、上記(2)項で引用されている委託業者に指定廃棄物を送り届けてから 30 日以内に、上記(5)項で引用されている指定施設の所有者から、附則 6 のコピーを受理できなかった場合、廃棄物発生者は、直ちに環境局長に届け出て調査を行い、その調査結果を環境局長に通知しなければならない。

(7) 廃棄物発生者、委託業者または指定施設の所有者は各々、指定施設の所有者が指定廃棄物を引取った日から少なくとも 3 年間は、記録の保持という趣旨から、附則 6 の署名入りコピーを保管しなければならない。

13. 廃棄物発生者の施設外に指定廃棄物を運搬する場合に提出されなければならない情報

(1) 全ての廃棄物発生者は、委託業者に引き渡す指定廃棄物の各分類に関して、附則 7 に則った情報を提供しなければならず、廃棄物を委託業者に引き渡した際に、附則 7（の当該記載済みフォーム）を委託業者に提出しなければならない。

⑵ 廃棄物発生者は、附則 7 の目的と用途を委託業者に通知しなければならない。

⑶ 委託業者は、運搬されてくる指定廃棄物の分類毎に附則 7（の記載済みフォーム）を所持し、同指示に注意を払い、その規定を遵守しなければならない。

⑷ 委託業者は、運搬ルートの選択に当たって、人口密度の高い地域、集水地域やその他の環境的に脆弱な地域をできる限り避けるように対応しなければならない。

⑸ 委託業者は、指定廃棄物の取り扱い、運搬及び保管に携わる全ての従業員が、関連研修プログラムに確実に参加するようにしなければならない。

⑹ 委託業者は、附則 7 フォームの目的及び用途について、当該研修プログラムの期間中に従業員一人一人に周知徹底させなければならない。

14. 漏洩及び流出事故

⑴ いかなる指定廃棄物の漏洩または流出事故が起こった場合でも、廃棄物に対して責任を持つ委託業者は、事態を直ちに環境局長に通知しなければならない。

⑵ 契約業者は、漏洩物や流出事故を封じ込め、洗浄し、あるいは除去するため、また漏洩や流出事故に係わる物質を回収するため、実施可能なあらゆる対応を行わなければならない。

⑶ 廃棄物発生者は、上記⑵項で規定されたあらゆる洗浄活動で、専門技術及び協力支援を提供しなければならない。

⑶ 委託業者は、環境保局長が定める一定期間、漏洩または流出事故による環境影響について、調査・研究を行わなければならない。

15. 研修の実施

全ての廃棄物発生者は、指定廃棄物の識別、取り扱い、表示、運搬、保管及び漏洩または流出への対応に携わる全ての従業員が、関連研修プログラムに確実に参加するようにしなければならない。

16. 違反行為の解決

(1) これら諸規則の遵守に対する不作為または怠慢による違反行為、あるいは諸規則に反して企てられたあらゆる違反行為は、環境保全法 1974 の第 45 条に基づき解決される。

(2) 上記(1)項で引用されている違反行為の解決は、環境保全（違反行為の解決）規則 1978 [P.U. (A) 281/1978]で規定されている手順に沿って行われなければならない。

17. 廃止

環境保全（指定廃棄物）規則 1989 [P.U. (A) 139/1989] は、廃止する。

附則 1

（規則 2）

SW1　　　金属及び金属を含む廃棄物

SW101　　砒素または砒素化合物を含む廃棄物

SW102　　鉛蓄電池の廃棄物（形がそのままのもの、あるいは破砕された形のもの）

SW103　　カドミウム及びニッケルまたは水銀あるいはリチウムを含む廃電池（battery）

SW104　　砒素、水銀、鉛、カドミウム、クロム、ニッケル、銅、バナジウム、ベリリウム、アンチモン、テルル、タリウム、またはセレンを含むダスト、スラグ、ドロスまたは灰。ただし、製鉄所から生ずるスラグは除く。

SW105　　めっきスラッジ

SW106　　酸洗い液の回収残さ

SW107　　銅の処理工程で、砒素、鉛またはカドミウムを用いた追加の加工または精錬から生ずるスラッジ

SW108　　亜鉛処理から生じる灰状及びスラッジ状の浸出残さ（leaching residues）

SW109　　水銀または水銀化合物を含む廃棄物

SW110　　蓄電池（accumulators）、水銀スイッチ、ブラウン管（CRT）ガラスやその他の活性ガラスまたはポリ塩化ビフェニール（PVC）コンデンサーなどの部品を含むか、あるいはカドミウム、水銀、鉛、ニッケル、クロム、銅、リチウム、銀、マンガンまたは PVC によって汚染された電気電子組立品の廃棄物

SW2　　　金属や有機材料を含む可能性がある主に無機成分を含む廃棄物

SW201　　スラッジ、灰または繊維状のアスベスト廃棄物

SW202　触媒の廃棄物

SW203　化学的に固定化、カプセル化、固形化または不活性化されたスラッジを含む固定化された指定廃棄物

SW204　クロム、銅、ニッケル、亜鉛、鉛、カドミウム、アルミニウム、スズ、バナジウム及びベリリウムの一つまたはいくつかの金属を含むスラッジ

SW205　化学産業または発電所から生ずる石こう廃棄物

SW206　使用済み無機酸

SW207　フッ化物を含むスラッジ

SW3　金属及び無機素材を含む可能性がある主として有機成分を含む廃棄物

SW301　pH 2 以下の腐食性、または有害な使用済み有機酸

SW302　有機酸、溶剤または塩化アンモニウム化合物の混合物を含む使用済みフラックス

SW303　固体高分子材料を除く有機溶剤を含む使用済み接着剤または粘着物廃液

SW304　グリセリン石鹸溶液の前処理（pretreatment of glycerol soap lye）から生ずるプレスケーキ

SW305　廃潤滑油

SW306　廃油圧／作動油

SW307　廃鉱油－水の乳濁液

SW308　オイルタンカー・スラッジ

SW309　バラスト水のような油と水の混合液

SW310	鉱油貯水槽のスラッジ
SW311	廃油または油性スラッジ
SW312	自動車整備場、サービスステーションのオイルまたはグリース・インターセプターから生ずる油性残留物
SW313	廃潤滑油の再精製から生ずる油で汚染された土壌
SW314	石油精製プラントのメンテナンス作業から生ずる油またはスラッジ
SW315	石油精製、石油化学プラントから生ずるタールまたはタール状の残さ
SW316	酸性スラッジ
SW317	四エチル鉛、四メチル鉛及び有機スズ化合物を含む廃有機金属化合物
SW318	ポリ塩化ビフェニール（PCB）またはポリ塩化トリフェニール（PCT）を含む、もしくはこれらによって汚染された廃棄物、物質及び成形品
SW319	液体状またはスラッジ状のクロロフェノールを含むフェノールあるいはフェノール化合物の廃棄物
SW320	ホルムアルデヒドを含む廃棄物
SW321	有機溶剤ないし重金属を含むゴムまたはラテックスの廃棄物もしくはスラッジ
SW322	非ハロゲン化有機溶剤の廃棄物
SW323	ハロゲン化有機溶剤の廃棄物
SW324	有機溶剤の回収作業から生ずる非水溶性の蒸留残さ（ハロゲン化されているかいないかを問わない）の廃棄物
SW325	エポキシ樹脂及びフェノール樹脂を含む有機溶剤または重金属を含む未処

理（uncured）樹脂の廃棄物

SW326	有機リン化合物の廃棄物
SW327	エチレングリコールなどの熱流体（熱伝達用）廃棄物
SW4	無機物または有機物を含む廃棄物
SW401	重金属を含む廃アルカリ
SW402	pH 11.5 以上の腐食性または有害な廃アルカリ
SW403	向精神薬物質または有毒性、有害性、発がん性、変異誘発性ないし催奇形性の物質を含む廃棄された薬物
SW404	病原性廃棄物、医療廃棄物または検疫隔離物
SW405	製薬品の調合及び製造から生ずる廃棄物
SW406	指定廃棄物焼却炉から生じるクリンカー、スラグ及び灰
SW407	ダイオキシンまたはフランを含む廃棄物
SW408	化学合成油、鉱油または指定廃棄物の漏洩の洗浄から生ずる汚染土壌、破片または物質
SW409	化学品、殺虫剤、鉱油または指定廃棄物によって汚染された、処分される容器、ゴミ袋または機器
SW410	指定廃棄物で汚染されたぼろ切れ、プラスチック、紙またはフィルタ
SW411	飲料水処理、食品産業及びビタミンの製造工程から生ずる炭素を除く廃活性炭
SW412	シアン化物を含むスラッジ

SW413	シアン化物を含む廃塩
SW414	シアン化物を含む廃アルカリ性水溶液
SW415	シアン化物を含む廃冷却油
SW416	インキ、塗料、顔料、ラッカー、染料またはワニスのスラッジ
SW417	インキ、塗料、顔料、ラッカー、染料またはワニスの廃棄物
SW418	有機溶媒を含む、廃棄されたまたは不良（off-specification）のインキ、塗料、顔料、ラッカー、染料あるいはワニス
SW419	フォームの製造工程から生ずる固体高分子材料を除く廃ジイソシアネート及びイソシアネート化合物の残さ
SW420	指定廃棄物の埋立地から生ずる浸出液／水
SW421	指定廃棄物の混合物
SW422	指定廃棄物及び非指定廃棄物の混合物
SW423	廃現像液、廃棄された写真用化学薬品または廃棄された写真関連廃棄物
SW424	廃酸化剤
SW425	殺虫剤、除草剤または殺生物剤の製造、調合、取引（trade）または使用から生ずる廃棄物
SW426	殺虫剤、除草剤または殺生物剤の製造、調合、取引（trade）または使用から生ずる不良品
SW427	水酸化カルシウム・スラッジ、リン酸処理スラッジ、カルシウム亜硫酸塩スラッジ、炭酸塩スラッジを含む鉱物スラッジ
SW428	銅、クロムまたはフッ化ヒ素化合物を含む無機塩、あるいは塩素化された

フェノールまたはクレオソートを含む化合物を使用した木材防腐作業から生ずる廃棄物

SW429 捨てられた、または不良の化学品

SW430 実験用の廃化学品（Obsolete laboratory chemicals）

SW432 過酸化物を含むか、過酸化物から構成されているか、または過酸化物によって汚染されている廃棄物

SW5 その他の廃棄物

SW501 指定廃棄物の処理またはリカバリーから生ずるあらゆる残さ

附則 2
（規則 3）

環境保全法 1974

環境保全（指定廃棄物）規則 2005

指定廃棄物に関する届出

（コピー2 部を作成のこと）

ファイル Ref. No.：
廃棄物発生者コード：
州コード：

1．身元確認

（ｉ）施設名及び同所在地：

....

....

....

....

Tel. No.：.............................. Fax No.：.............................. Telex No.：..............................

（ⅱ）施設所有者：..

役職名：..

2． 生産データ
毎月使用する原材料／化学品及び量のリスト*

原材料／化学品	量（トン）

3．廃棄物データ
毎月発生する指定廃棄物**

廃棄物分類コード	廃棄物発生源 1	廃棄物名	廃棄物成分 2	量（トン／月）3

注：1．工場／工程内の生産過程の単位（Unit Operation in the process/ plant）
2．元素、化合物または素材の名称
3．換算単位（トン／月単位によるデータのみ容認）
*必要に応じて追加のシートを利用
**推定

提供する情報は、下名の知識に基づく限り、真正かつ正確であることをここに誓います。

………………………………………………………………
報告者の署名***
氏名：………………………………………………………
役職名：……………………………………………………
日付：………………………………………………………

注：
***報告者とは、指定廃棄物を取り扱う者を指す。

附則 3
（規則 10）

指定廃棄物・爆発物（廃棄物）への表示要件

記号（爆発する爆弾）：黒；背景：明るいオレンジ

表示 1 [図省略]

引火性液体類（廃棄物）

記号（炎）：黒または白；背景：赤

表示 2 [図省略]

可燃性固体（廃棄物）

記号（炎）：黒；背景：白、垂直の赤ストライプ入り

表示 3 [図省略]

固体：自然発火性物質（廃棄物）

自然発火し易い物質

記号（炎）：黒；背景：上部白、下部赤

表示 4 [図省略]

固体：水反応可燃性物質（廃棄物）

水と作用して、引火性ガスを放出する物質

記号（炎）：黒または白；背景：青

表示 5 [図省略]

酸化性物質（廃棄物）

記号（丸の上に炎）：黒；背景：黄

表示 6 [図省略]

有機過酸化物（廃棄物）

記号（丸の上に炎）：黒；背景：黄

表示 7 [図省略]

毒物（廃棄物）

有毒（毒性）物質

記号（交差した骨の上に頭蓋骨）：黒；背景：白

表示 8 [図省略]

感染性物質（廃棄物）

記号（丸の上に重なった 3 つの三日月）：黒；背景：白

表示 9 [図省略]

腐食性物質（廃棄物）

記号（2 つのガラス容器からこぼれた液体が、手と金属に損傷を与えている）：黒；背景：上部白、下部黒

表示 10 [図省略]

種々雑多な危険性物質の混合物（廃棄物）

記号（なし）；背景：白、上半分に垂直の黒ストライプ

表示 11 [図省略]

表示の詳細

1. 表示は、45 度に傾けられた正方形上のものでなければならない。表示の寸法は、容器、または包装証明書のサイズの関係上、より小さな表示でなくては収まらない場合を除き、10cm×10cm 未満であってはならない。

2. 表示 1～11 で用いられる色は、以下のとおり、英国規格 BS381C「指定目的用の色」に適合していなければならない。

色		Ref. No.
フレンチ・ブルー	・・　・・　・・	166
カナリヤ・イエロー	・・　・・　・・	309
シグナル・レッド	・・　・・　・・	537
明るいオレンジ	・・　・・　・・	557

3. 表示は、二分割されていなければならず、上部は絵記号を記すため、下部はブロック体による文字の印字のために確保されている。

4. 全ての表示の活字は、表示の背景が黒、赤、または青である場合（背景がこのいずれかの場合は、白で印字）を除き、黒で印字しなければならない。

5. 表示は、以下のいずれかの形態を成していれば良い。
（a）貼付け表示
（b）金属プレート、もしくは、
（c）容器または包装材に直に刷り込むか、または印刷する

6. 全ての表示は、効果を著しく損なうことなく、屋外の天候に耐え得るものでなければならない。

7. 表示は、対照的な色を背景にした箇所に貼付けなければならない。

8. 2 つ以上のハザードを引き起こす廃棄物である場合、その全てのハザードが表記されるよう、当該廃棄物はそれに応じた表示が貼付けられていなければならない。

附則 4
（規則 2）

潜在的に混合できない指定廃棄物
グループ A とグループ B の廃棄物を混合した場合、次のような潜在的影響がある。

グループ 1-A	グループ 1-B
カセイアルカリ浴（Alkaline caustic liquids）	硫酸スラッジ
アルカリ性洗浄剤	化学洗浄剤
腐食性アルカリ溶液	電解溶液、酸
腐食性廃液	エッチング酸、溶液または溶剤
石灰スラッジ及びその他の腐食性アルカリ	酸洗い液及びその他の腐食性酸
	使用済み酸
	使用済み混合酸

潜在的影響：発熱、過激反応

グループ 2-A	グループ 2-B
アスベスト	溶液
ベリリウム	爆発物
すすぎ落としをしていない殺虫剤容器	石油
殺虫剤	油及びその他の易燃性廃棄物

潜在的影響：発火または爆発時に有害物質を放出

グループ 3-A	グループ 3-B
アルミニウム	グループ 1-A または 1-B の廃棄物
ベリリウム	
カルシウム	
リチウム	
マグネシウム	
カリウム	
ナトリウム	
亜鉛粉末、その他の反応性金属及び金属水素化物	

潜在的影響：発火または爆発。引火性水素ガスの発生

グループ 4-A	グループ 4-B
アルコール類	濃縮されたグループ 1-A または 1-B に属する廃棄物
	カルシウム
	リチウム
	金属水素化物
	カリウム
	ナトリウム
	水反応性廃棄物

潜在的影響：発火、爆発または発熱。引火性有毒ガスの発生

グループ 5-A	グループ 5-B
アルコール類	濃縮されたグループ 1-A または 1-B に属する濃縮廃棄物
アルデヒド	グループ 3-A 廃棄物
ハロゲン化炭化水素	
ニトロ化炭化水素などの反応性有機化合物及び溶剤	
不飽和炭化水素	

潜在的影響：発火、爆発、または過激反応

グループ 6-A	グループ 6-B
シアン系廃液及び硫化物溶液	グループ 1-B 廃棄物

潜在的影響：有毒性シアン化水素または硫化水素ガスの発生

グループ 7-A	グループ 7-B
塩素酸塩及びその他の強酸化剤	有機酸

グループ 7-A	グループ 7-B
亜塩素酸塩	グループ 2-B 廃棄物
クロム酸	グループ 3-B 廃棄物
次亜塩素酸塩	グループ 5-A 廃棄物及びその他の易燃性、可燃性廃棄物
硝酸塩	
硝酸	

過塩素酸塩
過マンガン酸塩
過酸化物

潜在的影響：発火、爆発または過激反応

附則 5
（規則 11）

環境保全法 1974

環境保全（指定廃棄物）規則 2005

目録（インベントリー）：指定廃棄物

所在地：...

a.*日付	*廃棄物分類コード	*廃棄物の名称	*発生量（トン）	廃棄物の取扱い		
				b.方法	量(トン)	c.場所

*指定廃棄物の現状発生インベントリー

a．指定廃棄物が最初に発生した日付

b．保管、処理、指定廃棄物からの材料または製品の回収、焼却、転換あるいはその他の方法（明細を記載）

c．施設の名称、住所を記載せよ

本フォームに記載した全ての情報は、下名の知識と信念に基づく限り、全ての面で、真正かつ正確であることをここに誓います。

報告者氏名：...

役職名：...

署名欄：.. 日付：...

I.C.番号：...

附則 6

（規則 12）

環境保全法 1974

環境保全（指定廃棄物）規制 2005

指定廃棄物の委託文書

Ⅰ．廃棄物発生者

ファイル Ref. No.：

廃棄物発生者コード：

州コード：

廃棄物発生者名：..

住所：..

責任者氏名：..

Tel. No.：........................ Fax No.：........................ Telex No.：........................

廃棄物名：.. 廃棄物分類コード：

廃棄物成分：..

廃棄物発生源：........................ 廃棄物発生源コード：

廃棄物のタイプ：

固形：..............

スラッジ：..............

液体：..............

廃棄物の包装：

パレット容器:..................................

密封容器：..

ドラム缶（55 ガロン）：..

その他（記載要）：..

量：............................（トン）　記入可能であれば：..........................（㎥）

処理・処分コスト：................................（リンギット：RM）／トン

最終仕向地の名称及び住所：

....

引渡し日：......................　..

責任者の署名

引渡し時間：...

Ⅱ. 委託業者

委託業者コード：

州コード：

委託業者名：………………………………

住所：………………………………

責任者氏名：………………………………

Tel. No.：……………… Fax No.：……………… Telex No.：………………

車両登録 No.：………………………………

運転手氏名：………………………………

一時保管の有無：いいえ：………………はい：………………

住所：………………………………

引取り日：……………… 運転手の署名：………………

引取り時間：………………

Ⅲ．保管／処理／　　　　　　　施設コード：
リカバリー／処分／　　　　　州コード：
施設運営者

施設名：..............................

施設所在地：..............................

責任者氏名：..............................

Tel. No.：.............. Fax No.：.............. Telex No.：..............

運営形態：

保管：..............

再分別化（regrouping）：..............

リカバリー：..............

埋立：..............

安全な埋立（secure landfill）：..............

物理／化学的処理：..............

焼却炉：..............

その他（記載）：..............

廃棄物量：..............（トン）、記入可能であれば：..............（㎥）

引取り日：..............　署名：..............

引取り時間：..............

附則 7
（規則 13）

情報

A. 特性

１. 分類
- 附則 1 に基づき記載

2. 発生源
- 廃棄物がどのようなプロセス、活動、発生などを経て、生じたのかを記載

3. 廃棄物の物理的特性
- 引火点 ℃
- 沸点 ℃
- 室温での状態（気体、液体、スラッジ、固体）
- 空気よりも軽い／重い気体
- 水中における溶解度
- 水よりも軽い／重い廃棄物

4. リスク
- 吸入による
- 経口摂取による
- 経皮接触による

B. 廃棄物の取扱い

1. 身体保護機材
- 手袋、ゴーグル、防顔マスク, etc.

2. 取扱い、包装、輸送及び保管上の手順／注意事項

3. 適切な表示
- 容器用の表示

4．推奨される処分方法

C．身体損傷を引き起こす漏洩または流出事故の場合の注意事項

1．ガスを吸入、または経口摂取した場合
- （想定される）中毒症状
- 適切な応急措置
- 医師のためのガイドライン

2．経皮接触または目に入った場合
- （想定される）中毒症状
- 適切な応急措置
- 医師のためのガイドライン

D．以下により、器物の損傷を招く漏洩または流出事故の場合に講じられる手順

1．床、土、路面, etc.への漏洩

2．水中への漏洩

3．発火

4．爆発

巻末付属資料 2

GUIDELINES ON ENVIRONMENTALLY SOUND CO-PROCESSING OF SCHEDULED WASTES IN CEMENT INDUSTRY IN MALAYSIA

DEPARTMENT OF ENVIRONMENT MALAYSIA

GUIDELINES ON ENVIRONMENTALLY SOUND CO-PROCESSING OF SCHEDULED WASTES IN CEMENT INDUSTRY IN MALAYSIA

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1.0 INTRODUCTION

1.1 Management of scheduled wastes in Malaysia has been implemented based on the cradle to grave principle. However, in line with the development of new technology and current practice in the waste management hierarchy which promote reuse or recycling or reutilization of waste, a transformation in the waste management to another process-integrated technology, advocated as cradle to cradle approach has emerged. This approach promotes the use of waste whenever possible, as alternative raw material or alternative fuel to substitute the raw material, without jeopardizing the quality of the same product. This will subsequently eliminate the need for waste disposal to landfills.

1.2 Shifting attitudes and better understanding from all stakeholders with regards to the importance of conserving the natural resource and pollution prevention to protect the environment, this waste to wealth practice has shown an increasing trend globally, as well as in Malaysia. Nowadays, industries in Malaysia have shown their interest to choose the disposal of waste to landfills as the last option, by sending the scheduled waste to recovery facilities to recover the valuable components, as well as to be co-processed in cement industries as alternative raw material and cement additives.

1.3 Co-processing is the use of scheduled waste as a raw material or as a source of energy or both as an alternative to natural mineral resources and fossil fuel in cement production.

1.4 Co-processing of wastes in properly controlled cement kilns provides energy and materials recovery while cement is being produced, offering an environmentally sound recovery option for many waste materials. Properly controlled co-processing can provide a practical, cost-effective and environmentally preferred option to landfill and incineration. In general, co-processing of waste in resource-intensive processes can be an important element in a more sustainable system of managing raw materials and energy.

1.5 Scheduled wastes to be used as alternative raw material or alternative fuel or additives in cement industries have certain components or characteristics that make them suitable for such purpose. Examples of scheduled waste which has been approved by Department of Environment to be co-processed by cement plant in Malaysia are as in **Table 1**:

Purpose of co-processing	**Waste code under First Schedule, Environmental Quality (Scheduled Waste) Regulations 2005**	**Type of waste**
Alternative raw material	SW 104	Used copper slag Used garnets Spent pot linings

	SW 204	Sludges containing one or several metals including chromium, copper, nickel, zinc, lead, cadmium, aluminium, tin, vanadium and beryllium
	SW 207	Sludges containing flouride
Cement additive	SW 104	Fly ash from coal-based powerplant
	SW 205	FGD gypsum from power plant (i.e. not necessary be coal based) Gypsum from chemical plant

Table 1: Examples of scheduled wastes approved for co-processed in cement industry

2.0 SCOPE

These guidelines are prepared to promote and facilitate the cement industry to plan and implement co-processing activities in their plant in an environmentally sound manner, without jeopardising the quality of cement.

3.0 OBJECTIVE

These guidelines are prepared as a guidance document for cement plants who intend to use scheduled wastes as alternative raw material and/or alternative fuel and/or cement additive in the production of cement product, in an environmentally sound manner.

These guidelines will also:

(a) Promote waste-to-wealth concept.

(b) Outline the legal requirement and procedure to implement co-processing activity in cement plant.

(c) Ensure the implementation of co-processing activity in cement plant is in compliance with Environmental Quality Act 1974 and all Regulations, Order and Rules under the Act.

4.0 DEFINITION

For the purpose of these guidelines, the definitions of terms used are as follows:

Aggregates	Particulate materials used in construction such as sand, gravel, crushed stone and crushed slag
Alkali bypass	A duct located between the feed end of the kiln and the preheater tower. A portion of the kiln exit gas is withdrawn through this and quickly cooled by air or water to avoid excessive alkali, chloride and sulphur build-up on the raw feed. This is also known as kiln exhaust gas bypass.
Alternative fuels and raw materials (AFR)	Inputs to clinker production derived from waste streams that contribute energy and/or raw material.
Alternative fuels	Wastes with recoverable energy value, used as fuels in a cement kiln, replacing a portion of conventional fossil fuels such as coal. Other terms include: secondary, substitute or waste derived fuels.
Alternative raw materials	Waste materials containing useable minerals such as calcium, silica, alumina and iron, which can be used in the kiln to replace raw materials such as clay, shale and limestone. Also known as secondary or substitute raw materials.
Best available techniques (BAT)	The most effective methods of reducing emissions and the impact on the environment as a whole.
Bypass dust	Dust discarded from the bypass systems of the suspension preheater, precalciner and grate preheater kilns, consisting of fully calcined, kiln feed material.
Calcination	Heat-induced removal, or loss of chemically-bound volatiles other than water. In cement manufacture this is the thermal decomposition of calcite (calcium carbonate) and other carbonate minerals that gives a metallic oxide (mainly CaO) plus carbon dioxide.
Cement kiln dust (CKD)	The fine-grained, solid, highly alkaline material removed from cement kiln exhaust gas by air pollution control devices. Much of the CKD material is unreacted raw material, including raw mix at various stages of burning and particles of clinker. The term can be used to denote any dust from cement kilns, such as that coming from bypass systems.

Cement	Finely ground inorganic material that, when mixed with water, forms a paste that sets and hardens by means of hydration reactions and processes and that, after hardening, retains its strength and stability under water.
Cement additive	Substances added to impart or improve desirable properties or suppress undesirable properties of the cement.
Clinkering	The thermo-chemical formation of clinker minerals, especially to those reactions occurring above about 1,300° C; also the zone in the kiln where this occurs. Also known as sintering or burning.
Co-processing	The use of suitable waste materials in manufacturing processes for the purpose of energy and/or resource recovery and resultant reduction in the use of conventional fuels and/or raw materials through substitution.
Destruction and removal efficiency (DRE)	Efficiency in destruction and removal of a given organic compound. Mathematically, DRE is calculated as follows: DRE = [(*W*in – *W*out stack)/*W*in] × 100 where *W*in is the mass feed rate of one principal organic hazardous constituent (POHC) in the waste stream fed to the kiln, and *W*out stack is the mass emission rate of the same POHC in the exhaust emissions prior to release to the atmosphere.
Destruction efficiency (DE):	A measure of the percentage of a given organic compound that is destroyed by the combustion process. Mathematically, DE is calculated as follows: DE = [(*W*in – *W*out combustion chamber)/*W*in] × 100 where *W*in is the mass feed rate of one principal organic hazardous constituent (POHC) in the waste stream fed to the kiln, and *W*out combustion chamber is the mass emission rate of the same POHC leaving the kiln (upstream of all air pollution control equipment). The DE represents the fraction of the organics entering a kiln, which is actually destroyed; the DRE represents the fraction of the organics entering a kiln and emitted from the stack to the atmosphere
Dry process	Process technology for cement production. In the dry process, the raw materials enter the cement kiln in a dry condition after being ground to a fine powder called the raw meal. The dry process consumes less energy than the wet process, where water is added to the raw materials during grinding to form slurry.

Emissions testing	Manual collection of stack gas samples, followed by chemical analysis to determine pollutant concentrations.
Heating (calorific) value	The heat per unit mass produced by complete combustion of a given substance. Calorific values are used to express the energy values of fuels, usually expressed in megajoules per kilogram (MJ/kg).
Kiln line	The part of the cement plant that manufactures clinker; comprises the kiln itself, any preheaters and precalciners and the clinker cooler apparatus.
Kiln	The heating apparatus in a cement plant for manufacturing clinker. Unless otherwise specified, it may be assumed to refer to a rotary kiln.
Precalciner	A kiln line apparatus, usually combined with a preheater, in which partial to almost complete calcination of carbonate minerals is achieved ahead of the kiln itself, and which makes use of a separate heat source. A precalciner reduces fuel consumption in the kiln, and allows the kiln to be shorter, as it no longer has to perform the full calcination function.
Preheater	An apparatus for heating the raw mix before it reaches the dry kiln itself. In modern dry kilns, the preheater is commonly combined with a precalciner. Preheaters use hot exit gases from the kiln as their heat source.
Pre-processing	Alternative fuels and/or raw materials not having uniform characteristics must be prepared from different waste streams before being used as such in a cement plant. The preparation process, or pre-processing, is needed to produce a waste stream that complies with the technical and administrative specifications of cement production and to guarantee that environmental standards are met.
Raw mix/meal/feed	The crushed, ground, proportioned, and thoroughly mixed raw material-feed to the kiln line.
Recovery	Any operation where waste is serving a useful purpose by replacing other materials that would otherwise have been used to fulfil a particular function, or waste being prepared to fulfil that function, in the plant or in the wider economy.
Rotary kiln	A kiln consisting of a gently inclined, rotating steel tube lined with refractory brick. The kiln is fed with raw materials at its upper end and heated by flame from, mainly, the lower end, which is also the exit end for the product (clinker).
Trial burn	Emissions testing performed for demonstrating compliance with the destruction and removal efficiency (DRE) and destruction efficiency (DE) performance standards and

regulatory emission limits; is used as the basis for establishing allowable operating limits.

5.0 OVERVIEW OF CEMENT MANUFACTURING

5.1 The crucial constituent in concrete is cement. It is a non-metallic, inorganic fine powder, which will forms into paste, set and harden when mixed with water.

5.2 Cement production involves the heating, calcining and sintering of an accurate mix of calcareous and argillaceous materials, usually limestone and clay. This produces cement clinker, which is then cooled and ground with additives such as gypsum to make cement.

5.3 The most widely used production process is for Portland cement clinker, described in more detail in **Annex 1** of these guidelines.

5.4 Cement manufacturing is a resource intensive industry. It require about 1.5–1.7 tonnes of quarried raw material to produce a tonne of clinker, and the cement kilns require substantial energy with temperatures of over 2,000° C . Each tonne of cement produced typically requires 60–130 kilograms of fuel oil, or its equivalent, and about 105 KWh of electricity (Loréa, 2007). On average, energy costs of fuel and electricity represent 40 per cent of cement manufacturing costs (EIPPCB, 2010).

5.5 Clinker burning is the most important phase of the production process in terms of the environmental impact associated with cement manufacture. Depending on the specific production processes, cement plants cause emissions to air and waste emissions to land such as cement kiln dust (CKD). Other impacts to the environment are discharge to water, noise and odour pollution.

5.6 The pollutants released to air are particulates, nitrogen oxides (NO_X) and sulphur dioxide (SO_2), carbon oxides (CO, CO_2), polychlorinated dibenzo-p-dioxins and dibenzofurans (PCCDs/PCDFs), volatile organic compounds (VOC), metals and their compounds, hydrogen chloride (HCl) and hydrogen fluoride (HF). The type and quantity of air emissions depend on varying parameters, for example, the raw materials and fuels used and the type of process.

5.7 Cement manufacturing is also associated with impacts of resource extraction (fossil fuel, limestone and other minerals) upon environmental quality, biodiversity, landscape aesthetics and the depletion of non-renewable or slowly renewable resources, such as fossil fuels or groundwater (Battelle, 2002).

5.8 **Figure 1** illustrates the general overview of cement manufacturing process.

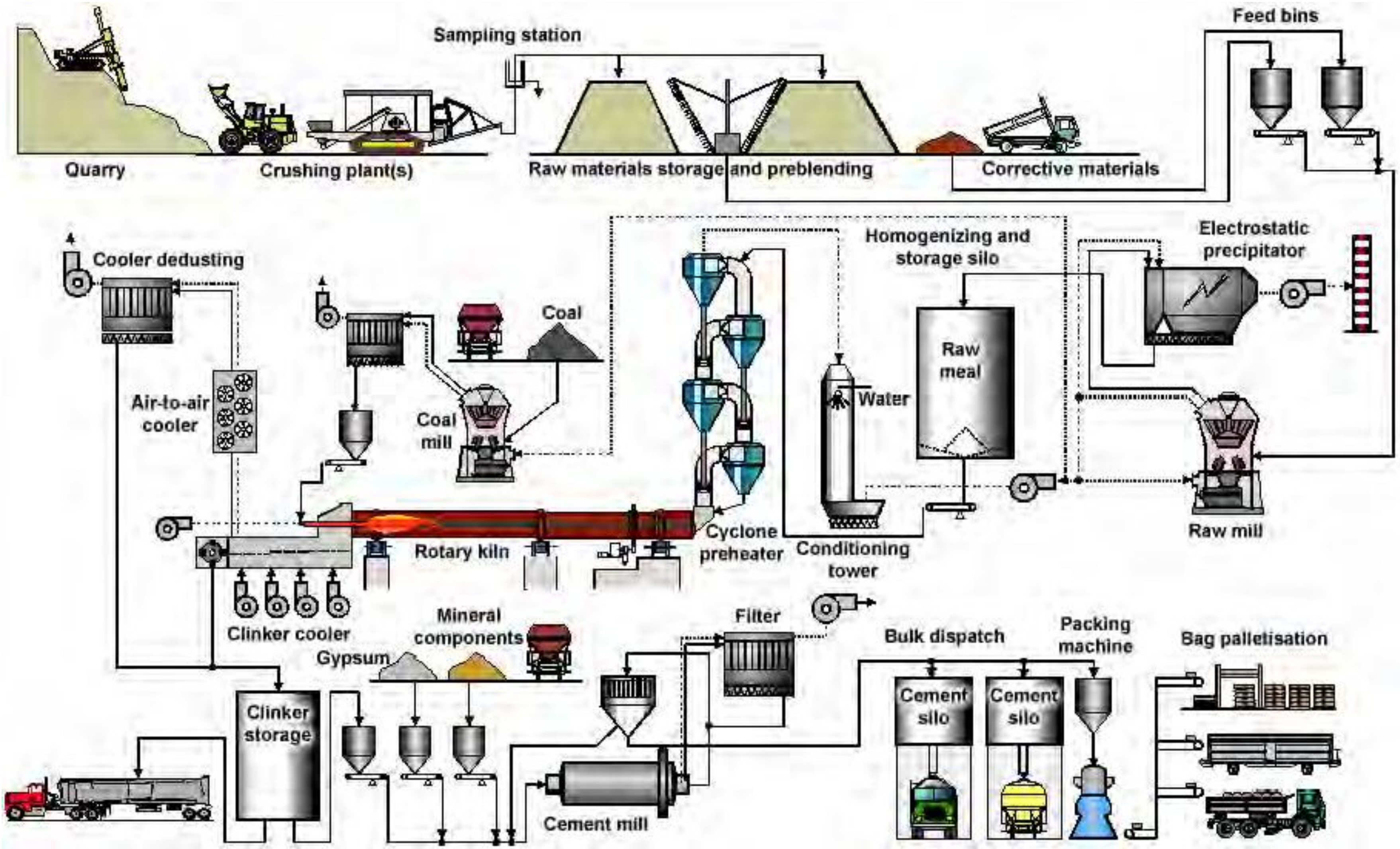


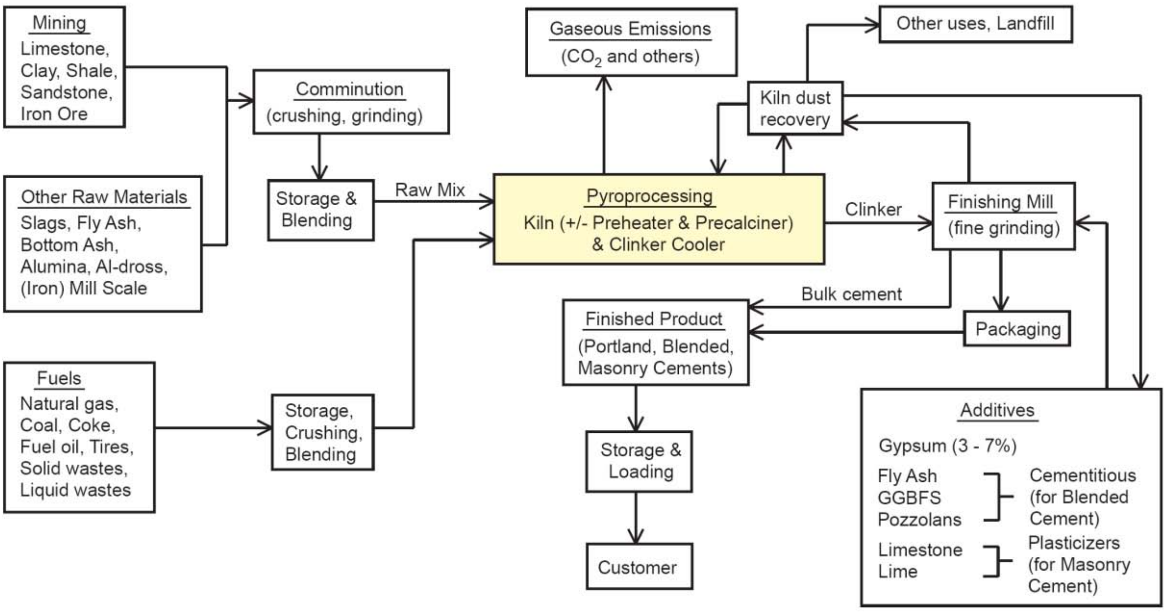
Figure 1: General overview of a cement manufacturing process
Source: CEMBUREAU (2006)

6.0 CO-PROCESSING OF SCHEDULED WASTE IN CEMENT KILNS

6.1 Overview

6.1.1 Co-processing involves the use of waste in manufacturing processes for the purpose of energy and resource recovery by substituting or reducing the use of conventional fuels and raw materials. In particular, the co-processing of scheduled waste in cement kilns allows the recovery of the energy and mineral value from waste while cement is being produced. Co-processing wastes serve a useful purpose in replacing materials that would have otherwise been used in cement manufacturing, thereby conserving natural resources. **Figure 2** provides a process flow diagram of the general cement manufacturing process

Figure 2 – Flow diagram of the general cement manufacturing process



Source: van Oss (2005)

Note:

1. *Fly ash used as other raw material referred to fly ash from incinerators, emission control equipments and etc. that fulfilled the Waste Acceptance Criteria for alternative raw material.*
2. *Fly ash used as additive referred to fly ash coal-based power plant that fulfilled the Waste Acceptance Criteria for cement additive.*

6.1.2 Cement manufacture generally can consume significant quantities of wastes as fuel and alternative raw materials. This consumption reflects the process characteristics in clinker kilns, which ensure the complete breakdown of the raw materials into their component oxides and the recombination of the oxides into the clinker minerals. The essential process characteristics for the use of hazardous and other wastes, fed to the kiln via appropriate feed points, can be summarized as follows (EIPPCB, 2010):

(a) Maximum temperatures of approximately 2,000° C (main firing system, flame temperature) in rotary kilns;

(b) Gas retention times of about 8 seconds at temperatures above 1,200° C in rotary kilns;

(c) Material temperatures of about 1,450° C in the sintering zone of rotary kilns;

(d) Oxidising gas atmosphere in rotary kilns;

(e) Gas retention time in the secondary firing system of more than 2 seconds at temperatures above 850° C; in the pre-calciner, the retention times are correspondingly longer and temperatures are higher;

(f) Solids temperatures of 850° C in the secondary firing system and/or the calciner;

(g) Uniform burnout conditions for load fluctuations due to the high temperatures at sufficiently long retention times;Destruction of organic pollutants because of high temperatures at sufficiently long retention times;

(h) Sorption of gaseous components such as HF, HCl, and SO_2 on alkaline reactants;

(i) High retention capacity for particle-bound heavy metals;\

(j) Short retention times of exhaust gases in the temperature range known to lead to formation of PCDDs/PCDFs;

(k) Simultaneous material recycling and energy recovery through the complete use of fuel ashes as clinker components;

(l) Product-specific wastes are not generated due to a complete material use into the clinker matrix (although some cement plants dispose of CKD or bypass dust);

(m) Chemical-mineralogical incorporation of non-volatile heavy metals into the clinker matrix.

6.1.3 Potential benefits possible through the use of hazardous and other wastes in cement manufacturing are the recovery of the energy content of waste, conservation of non-renewable fossil fuels and natural resources, reduction of CO_2 emissions, reduction in production costs, and use of an existing technology to treat hazardous wastes (see, for example, Mantus, 1992; Battelle, 2002; WBCSD, 2005; Karstensen, 2007b).

6.1.4 Co-processing of scheduled wastes in cement kilns shall be carried out only according to best available techniques (BAT) while meeting requirements set out for input, process and emission. **Table 2** outlined the general principles for co-processing of scheduled wastes and other wastes in cement kilns.

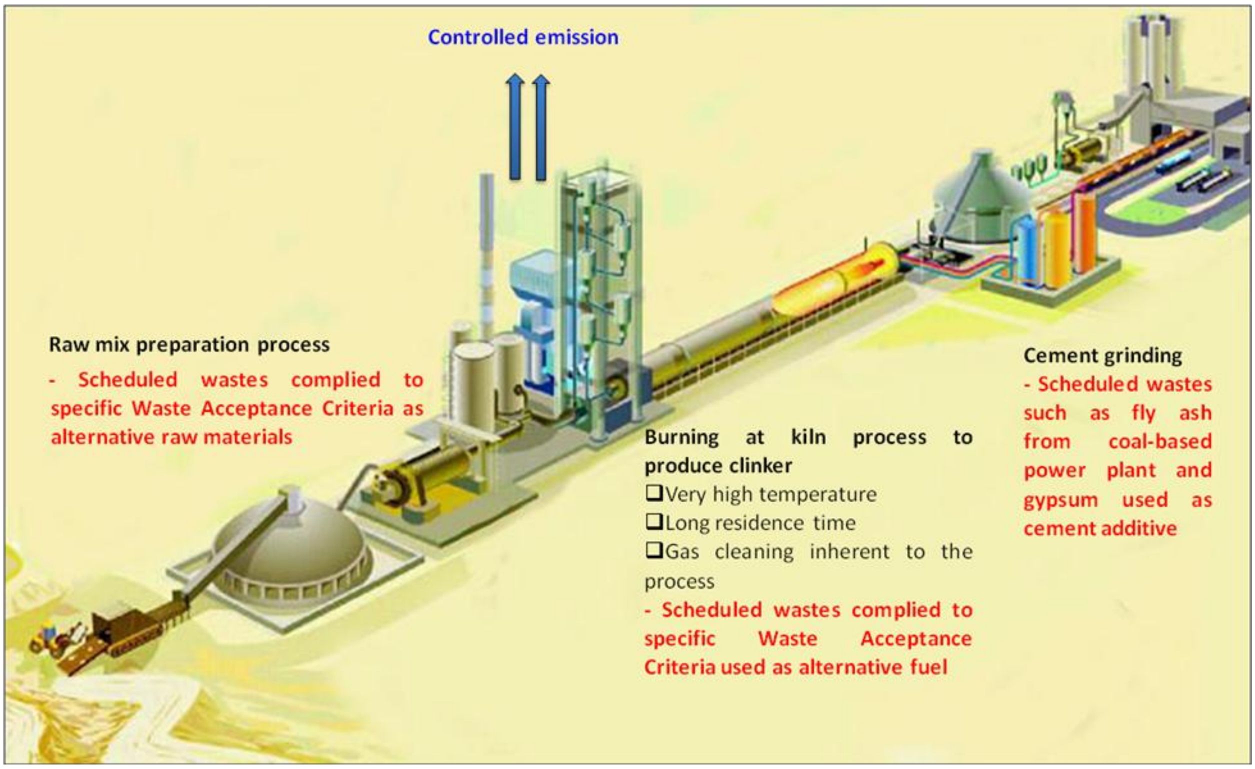
Principle	Description
The waste management hierarchy should be respected	– Waste should be co-processed in cement kilns where more ecologically and economically robust methods of recovery are not available – Co-processing should be considered an integrated part of waste management – Co-processing should be in line with the Basel and Stockholm Conventions and other relevant international environmental agreements
Additional emissions and negative impacts on human health must be avoided	– Negative effects of pollution on the environment and human health must be prevented or kept at a minimum – Air emissions from cement kilns co-processing waste cannot be statistically higher than those not involved in co-processing waste
The quality of the cement must remain unchanged	– The product (clinker, cement, concrete) must not be used as a sink for heavy metals – The product must not have any negative impacts on the environment (for example, as determined by leaching tests) – The quality of the product must allow for end-of-life recovery
Companies that co-process must be qualified	– Assure compliance with all laws and regulations – Have good environmental and safety compliance records – Have personnel, processes, and systems in place committed to protecting the environment, health, and safety – Be capable of controlling inputs to the production process – Maintain good relations with public and other parties involved in local, national and international waste management schemes

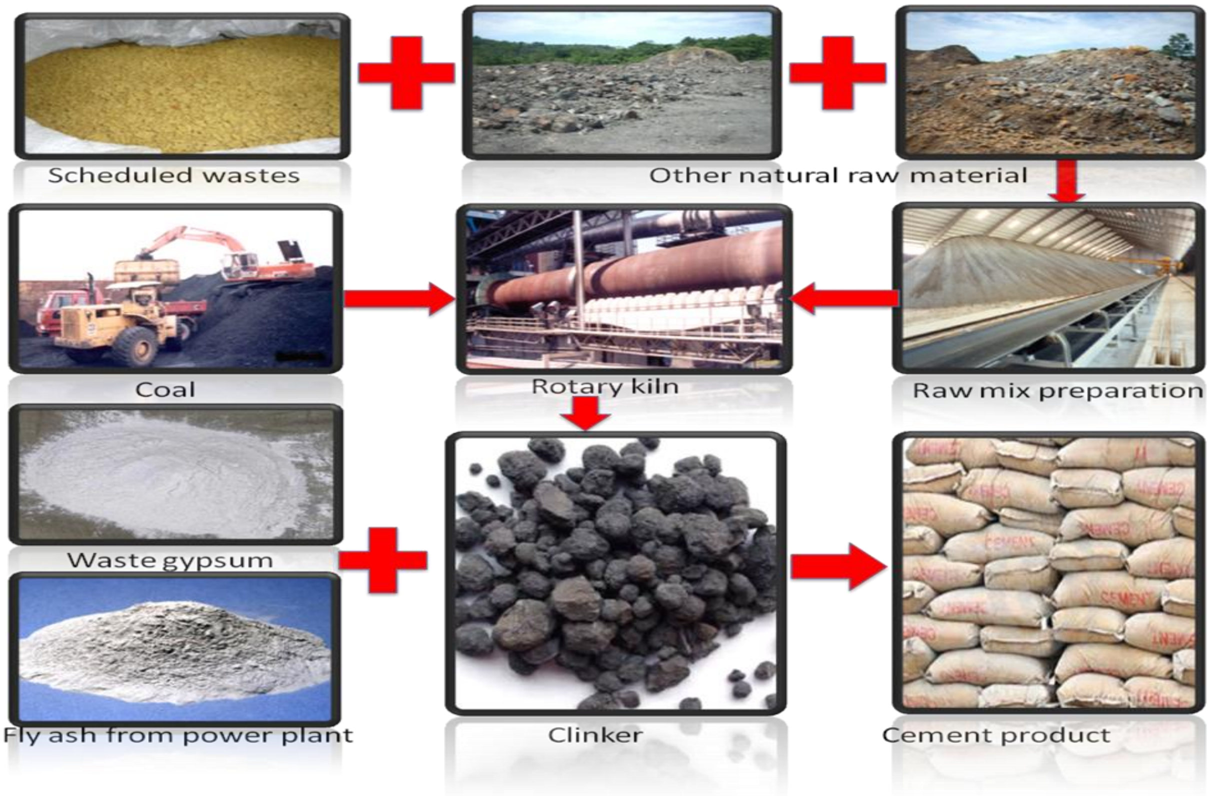
Table 2 - the general principles for co-processing of hazardous and other wastes in cement kilns

Source: GTZ (2006)

6.1.5 Figure 3 illustrates the use of scheduled wastes as alternative raw material, alternative fuel and cement additive in cement plant.

Figure 3 – Use of scheduled wastes in cement plant





6.2 Selection Of Wastes For Co-Processing

6.2.1 Co-processing should include a thorough selection of waste to avoid and/or reduce emissions and risk of damage to the environment or public health as well as to maintain the quality of cement products.

6.2.2 The use of scheduled wastes in cement manufacturing should add value to the process, for example the heating value and the material value of the mineral composition, while in compliance to the relevant regulations and permit requirements as well as the plant’s ability to handle any particular waste stream. The use of cement kilns as a disposal operation not leading to resource recovery (i.e., the destruction or irreversible transformation of scheduled wastes constituents), should be considered only if there are environmental benefits : for example, NOx reduction through flame cooling or when there is no other cost-effective and environmentally sound disposal option at the local level.

6.2.3 Blending and mixing of different scheduled wastes streams may be required to ensure a homogeneous feedstock of alternative raw material that meets specifications for use in a cement kiln. Blending of scheduled wastes should not, however, be conducted with the aim of lowering the concentration of hazardous constituents to circumvent regulatory requirements. As a general principle, the mixing of wastes should be prevented from leading to the application of an unsuitable (non-environmentally sound) disposal operation (EIPPCB, 2006) .

6.3 Scheduled Wastes Suitable For Co-Processing In Cement Kilns

6.3.1 The selection of suitable scheduled wastes to be used as alternative raw material in co-processing is influenced by various factors includes:

(a) the nature of the waste;

(b) its hazardous characteristics;

(c) available waste management operations;

(d) kiln operation; raw material and fuel compositions; waste feed points;

(e) exhaust gas cleaning process;

(f) resulting clinker quality;

(g) general environmental impacts;

(h) probability of formation and release of POPs;

(i) particular waste management considerations; and

(j) regulatory compliance; and public and government acceptance (Van Oss and Padovani, 2003; GTZ, 2006; UNEP, 2007; EIPPCB, 2010).

6.3.2 The operator should develop a waste evaluation procedure to assess potential impacts on the health and safety of workers and the public, plant emissions, operations and product quality, by taking the recommended variables as in **Table 3**, into consideration when selecting the waste (WBCSD, 2005; UNEP, 2007):

Variables		**Explanation**
Kiln operation	Alkali (sodium, potassium, etc.), sulphur and chloride content	• Excessive inputs of these compounds may lead to build-up and blockages in the kiln system. Where these cannot be captured in the cement clinker or kiln dust, a bypass may be required to remove excess compounds from preheater/precalciner kiln systems. High alkali content may also limit recycling of CKD in the kiln itself
	Heating (calorific) value	• The key parameter for the energy provided to the process
	Water content	• Overall moisture content may affect productivity, efficiency and also increase energy consumption. The water content of waste needs to be considered in conjunction with that of conventional fuels and/or raw feed materials
	Ash content	• The ash content affects the chemical composition of the cement and may require an adjustment of the composition of the raw mix
	Exhaust gas flow rate and waste feed rate	• Sufficient residence time is needed for the destruction of organics and to prevent incomplete combustion due to waste overcharging
	Others	• Stability of operation (for example, duration and

		frequency of CO trips) and the waste's state (liquid, solid), preparation (shredded, milled) and homogeneity
Emissions	Organic content	• Organic constituents are associated with emissions of CO_2 and may result in emissions of CO and other products of incomplete combustion (PICs) if waste is fed through unsuitable points or during unstable operating conditions
	Chloride content	• Chlorides may combine with alkalis to form fine, difficult to control particulate matter. In some cases, chlorides have combined with ammonia present in the limestone feed. This produces highly visible detached plumes of fine particulate with a high ammonium chloride content
	Metals content	• The non-volatile behaviour of most heavy metals allows most to pass straight through the kiln system and be incorporated into the clinker. • Introduced volatile metals will partly be recycled internally by evaporation and condensation until equilibrium is reached, the other part being emitted in the exhaust gas. • Thallium, mercury and their compounds are highly volatile as to a lesser extent are cadmium, lead, selenium and their compounds. • The fact that dust control devices can only capture the particle-bound fraction of heavy metals and their compounds needs to be taken into account. • Wood treated with preservatives containing copper, chromium and arsenic

		also requires special consideration with regard to the efficiency of the exhaust gas cleaning system. • Mercury is a highly volatile metal, which, depending on the exhaust gas temperature is present in both particle-borne and vapour forms in the air pollution control equipment (EIPPCB, 2010).
	Alkali bypass exhaust gas	• Alkali bypass exhaust gas can be released from either a separate exhaust stack or from the main kiln stack in systems equipped with an appropriate bypass. • According to the United States Environmental Protection Agency (1998) the same hazardous air pollutants are found in both the main and alkali bypass stacks. Where an alkali bypass system is installed, appropriate control of the exhaust to atmosphere also needs to be provided on the bypass exhaust, similar to that mandated for the main exhaust stack (UNEP, 2007)
	Sulphur content	• High sulphur content in raw materials, fuel and waste may result in the release of SO_2
Clinker, cement and final product quality	Phosphate content	• High levels of phosphate may delay setting time
	Flourine content	• High levels of fluorine will affect setting time and strength development
	Chlorine, sulphur and alkali content	• High levels chlorine, sulphur and alkali may affect overall product quality
	Thallium and chromium content	• Thallium and chromium content can adversely affect cement

		quality and may cause allergic reactions in sensitive users. • Leaching of chromium from concrete debris may be more prevalent than leaching of other metals (Van der Sloot et al., 2008). Leaching test is required to be carried out if the cement plant intends to use raw materials or scheduled wastes containing chromium. • Limestone, sand and clay contain chromium, making its content in cement both unavoidable and highly variable. The Norwegian National Institute of Occupational Health (Kjuus et al., 2003) reviewed several studies of chromate allergy, especially those involving construction workers. It found that the main sources of chromium in cement came from raw materials, refractory bricks in the kiln and chromium steel grinders. The relative contribution of these factors may vary depending on the chromium content of the raw materials and the manufacturing conditions. Minor sources include both conventional and alternative fuels (EIPPCB, 2010). • Cement eczema can be caused by exposure to wet cement with a high pH, which induces irritant contact dermatitis and by an immunological reaction to chromium that elicits allergic contact dermatitis (Kjuus et al., 2003). • Where there is a possibility of contact with the skin, cement and cement-containing preparations may not be used or placed on the market in the European Union, if they contain, when hydrated, more

		than 0.0002 per cent soluble chromium (VI) of the total dry weight of the cement. • As the main chromate source is from the raw material, a reduction in chromium levels (VI) in cement requires that a reducing agent is added to the finished product. The main reducing agents used in Europe are ferrous sulphate and tin sulphate (EIPPCB, 2010)
	Leachable trace elements:	• Heavy metals are present in all feed materials, conventional and otherwise. However under certain test conditions, leached concentrations from concrete of other metals besides chromium may approach drinking water standards (GTZ, 2006).

Table 3: Variables that should be taken in consideration when selecting Scheduled Wastes for co-processing

6.3.3 Only waste of known composition, energy and mineral value is suitable for co-processing in cement kilns. To verify the suitability of a particular scheduled wastes stream to be used in co-processing at their cement plant, the operators should develop a specific Waste Acceptance Criteria for each of the following purposes:

(a) Scheduled wastes used as alternative raw material;

(b) Scheduled wastes used as alternative fuel; and

(c) Scheduled wastes used as cement additive.

6.3.4. Cement plant shall establish the Waste Acceptance Criteria based on their plant's capability and the criteria should at least include the following parameters and limits:

<u>Waste Acceptance Criteria for alternative raw material:</u>

NOTE: ANALYSIS SHOULD BE IN DRY BASIS:

No.	Parameter	Minimum
1	SiO_2 (%)	Total of 2 major oxides should be >30% in dry basis
2	Fe_2O_2 (%)	

3	Al_2O_3 (%)		
4	CaO (%)		
5	Cl (ppm)	Maximum 2%. Waste with total halogenated organic with > 1% must be only used at the main burner	
6	Moisture content (%)	<u><</u>70 % in waste (subject to the characteristic of the waste)	
7	Pb (mg/kg)	<u>Total heavy metals:</u> <u><</u>100,000 ppm in ARM	
8	Cr (mg/kg)		
9	As (mg/kg)		
10	Sn (mg/kg)		
11	Se (mg/kg)		
12	Ni (mg/kg)		
13	Te (mg/kg)		
14	Co (mg/kg)		
15	V (mg/kg)		
16	Sb (mg/kg)		
17	Mn (mg/kg)		
18	Zn (mg/kg)	<30,000 in total input: ARM	
19	Cu (mg/kg)	<30,000 in total input: ARM	
24	Hg (mg/kg)	<10	<u>Total volatile metal:</u> <u><</u>100 ppm
25	Tl (mg/kg)	-	
26	Cd (mg/kg)	-	
27	Total organic content	<1% if ARM fed in cold part of the process	

Table 4: Minimum Waste Acceptance Criteria for scheduled waste used as alternative raw material

Waste Acceptance Criteria for alternative fuel:

NOTE: ANALYSIS SHOULD BE IN ASH BASIS:

No.	Parameter	Minimum	
1	Cl (ppm)	Maximum 2%. Waste with total halogenated organic with > 1% must be only used at the main burner	
2	Moisture content (%)	≤70 % in waste (subject to the characteristic of the waste)	
3	Pb (mg/kg)	Total heavy metals: ≤10,000 ppm in AF	
4	Cr (mg/kg)		
5	As (mg/kg)		
6	Sn (mg/kg)		
7	Se (mg/kg)		
8	Ni (mg/kg)		
9	Te (mg/kg)		
10	Co (mg/kg)		
11	V (mg/kg)		
12	Sb (mg/kg)		
13	Mn (mg/kg)		
14	Zn (mg/kg)	<30,000 in total input: AF	
15	Cu (mg/kg)	<30,000 in total input: AF	
16	Hg (mg/kg)	<10	Total volatile metal: ≤100 ppm
17	Tl (mg/kg)	-	
18	Cd (mg/kg)	-	
19	Calorific heating value	> 500 kcal/kg (as dried basis)	

Table 5: Minimum Waste Acceptance Criteria for scheduled waste used as alternative fuel

Waste Acceptance Criteria for cement additive

1. Low content of organic carbon

2. Does not contain radioactive component (example: Radon, ect.)

The cement plant shall ensure that the scheduled wastes received to be co-processed fulfilled the requirements specified in the Waste Acceptance Criteria before it is been sent to the cement plant to be co-processed.

6.3.5 The following scheduled wastes are not allowed for co-processing in cement kilns:

(a) Radioactive or nuclear waste;

Cement plants are not designed or operated to meet safety and health requirements for radioactive waste management. The preferred disposal approach is concentration (reduction of volume) and containment of radionuclides through a conditioning process to prevent or substantially reduce dispersion in the environment.

(b) Electric and electronic waste;

Electric and electronic waste contains valuable resources, such as precious metals and recycling should be the preferred option. Co-processing of plastic components might be an option but only after appropriate disassembly and sorting.

(c) Whole batteries;

Co-processing of batteries would lead to concentrations of pollutants in the cement and air emissions. Batteries contain valuable resources such as lead and recycling should be the preferred waste management option.

(d) Corrosive waste, including mineral acids;

Corrosive wastes may cause corrosion and fouling problems in equipment not specifically designed for this type of waste. This being usually the case with pre-processing, storage and injection systems. Wastes with high chlorine and sulphur contents such as some mineral acids may also have a negative effect on clinker production or product quality. High sulphur contents may also result in the release of sulphur oxides (UNEP, 2007).

(e) Explosives;

Explosive waste should not be co-processed in the cement kiln given the adverse effects on process stability. There are also occupational safety concerns due to the risk of uncontrolled explosions during transport and pre-processing activities.

(f) Cyanide bearing waste;

(g) Asbestos-containing waste;

(h) Infectious medical waste;

(i) Chemical or biological weapons destined to destruction;

(j) Waste consisting of, containing or contaminated with mercury above permitted limits;

The high volatility of mercury poses a problem regarding air emissions. Inputs of wastes consisting of, containing or contaminated with mercury to the kiln should be controlled and kept to a minimum

(k) Waste of unknown or unpredictable composition, including unsorted municipal waste.

In general these wastes are not recommended because of health and safety concerns, potentially negative impacts on kiln operation, clinker quality and air emissions, and when a preferable alternative waste management option is available

6.3.6 Scheduled wastes that are, in principle, well-suited for co-processing in cement kilns include: tank bottom sludges, acid alkyl sludges, oil spills and acid tars from petroleum refining, natural gas purification and pyrolytic treatment of coal; waste machining oils; waste hydraulic oils and brake fluids; bilge oils; oil/water separator sludges, solids or emulsions; washing liquids and mother liquors,still bottoms and reaction residues from the manufacture, formulation, supply and use of basic organic chemicals, plastics, synthetic rubber, man-made fibres, organic dyes, pigments, organic pesticides andpharmaceuticals; waste ink; wastes from the photographic industry; tars and other carbon-containing wastes from anode manufacture (aluminium thermal metallurgy); wastes from metal degreasing and machinery maintenance; wastes from textile cleaning and degreasing of natural products; process wastes from the electronic industry (GTZ/Holcim, 2006).

6.3.7 Waste streams with recoverable energy value meet specifications can be used as fuels in a cement kiln to replace a portion of conventional fuels and waste streams containing useful components such as calcium, silica, alumina and iron can be used to replace raw materials such as clay, shale and limestone. Wastes meeting both sets of requirements may be suitable for processing for both energy and materials recovery.

6.3.8 **Figure 4** outlined the decision to distinguish between operations that lead to resource recovery and disposal.

6.4 Trial Burns Of Scheduled Wastes For Co-Processing In Cement Kilns

6.4.1 A trial burn is used to determine the facility's destruction and removal efficiency (DRE) or destruction efficiency (DE), to verify its ability to efficiently destroy POPs in an irreversible and environmentally sound manner. This involves the selection, sampling and analysis of a principal organic hazardous constituent (POHC) in the waste feed to determine its input and emission rates. A trial burn typically consists of a series of tests, one for each set of operating conditions in the facility. Three runs are normally performed for each test.

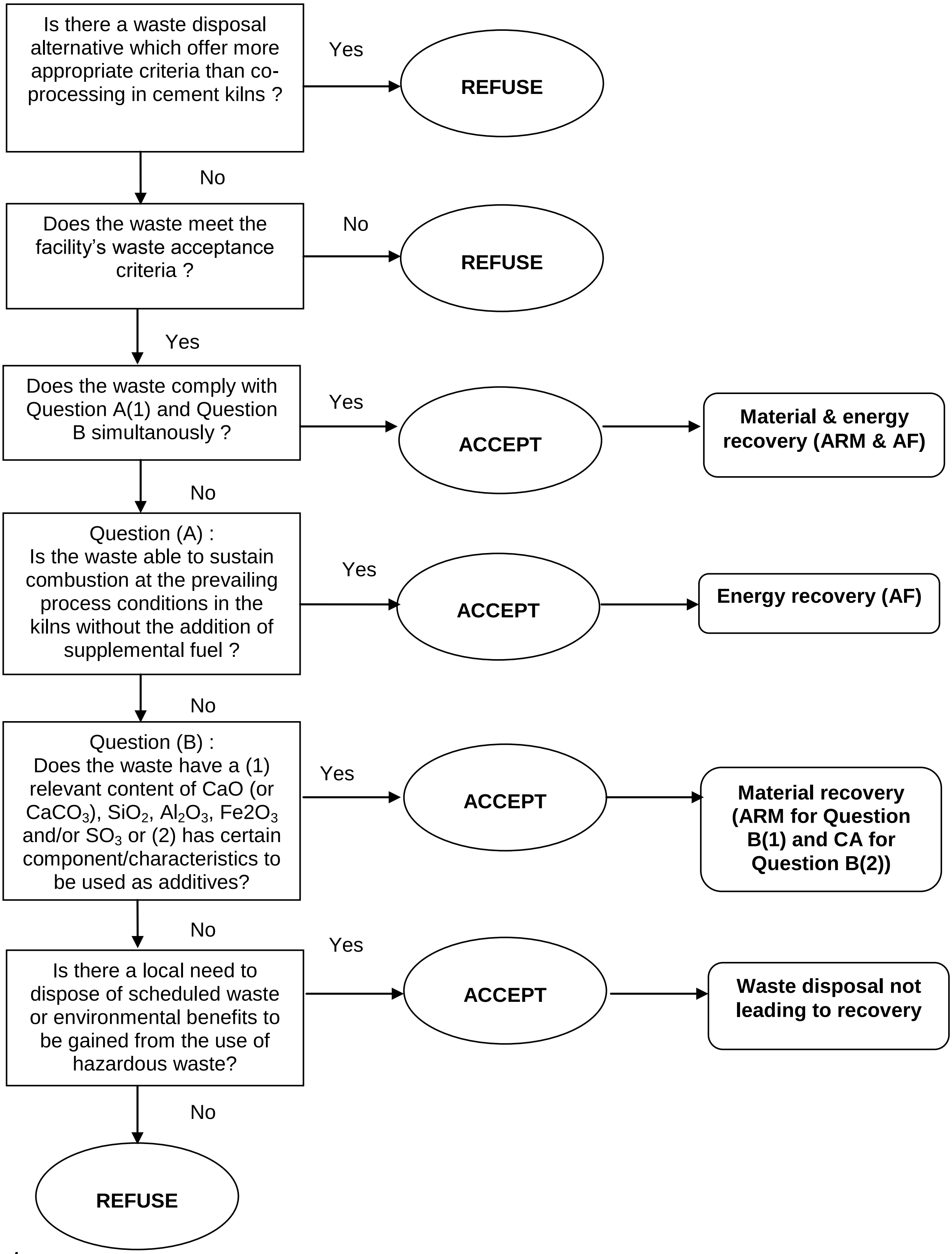
6.4.2 During the trial burn, the operator should establish the operating limits for maximum scheduled wastes feed and maximum kiln production rate. The operator shall also schedule a sampling and analysis of emission by competent and accredited party.

6.4.3 The trial burn should be carried out by existing or new cement plant intends to implement co-processing of scheduled wastes for the first time.

6.5 OTHERS

6.5.1 Other important aspects that should be taken into considerations when the operators of cement plant implement co-processing activity are the requirement for (i) a comprehensive programme on quality assurance (QA) and quality control (QC); (ii) health and safety program; and (iii) the involvement of stakeholders as well as public communication. Further information on three (3) aspects as outlined by UNEP are detailed out in **Annex 2**, **Annex 3** and **Annex 4**.

Figure 4: Decision to distinguish between operations that lead to resource recovery and/or disposal



Note:

ARM	**:**	**Alternative raw material**
AF	**:**	**Alternative fuel**
CA	**:**	**Cement additive**

7.0 ENVIRONMENTALLY SOUND CO-PROCESSING OF SCHEDULED WASTES IN CEMENT KILNS

7.1 Waste Acceptance And Pre-Processing

7.1.1 Before a cement plant decide to receive scheduled wastes to be used as alternative raw material, the operator should investigate the nature and composition associated with the waste, and all relevant information should be passed by the waste generator to the operator. The waste should also be sampled and sent to accredited laboratories for chemical analysis.

7.1.2 Operators of cement plant should ensure that the scheduled wastes received is in compliance to the Waste Acceptance Criteria of alternative raw material or alternative fuel that has been established beforehand.

7.1.3 The scheduled wastes usually will require a pre-processing to produce a homogeneous waste stream before it is co-processed in the cement kilns.

7.1.4 The operators shall develop a "Standard Operating Procedure" on Waste Acceptance and Pre-Processing that detailed out the management of scheduled wastes received to ensure it is manage properly and such activity will not give any adverse effect to the process, environment as well as human health. A general recommendation as outlined by UNEP as in **Annex 5**.

7.2 Co-Processing

7.2.1 For optimal performance (co-processing without additional emissions) alternative fuels and raw materials should be fed to the cement kiln through appropriate feed points, in adequate proportions and with proper waste quality and emission control systems.

7.2.2 Co-processing has the following characteristics during the production process (GTZ/Holcim, 2006):

(a) The alkaline conditions and the intensive mixing favour the absorption of volatile components from the gas phase. This internal gas cleaning results in low emissions of components such as SO2, HCl, and most of the heavy metals, with the exception of mercury, cadmium and thallium;

(b) The clinker reactions at 1450°C allow the chemical binding of metals and the incorporation of ashes to the clinker;

(c) The direct substitution of primary fuel by high calorific waste material causes a higher efficiency on energy recovery in comparison to other 'waste to energy' technologies.

7.2.3 A general recommendation as outlined by UNEP as in **Annex 6**.

8.0 QUALITY OF CEMENT PRODUCT

8.1 The cement product should comply with MS EN 197-1.

9.0 GOVERNMENT POLICY AND LEGAL REQUIREMENT

9.1 General Requirements

9.1.1 Below are the general requirements specific to cement kilns co-processing hazardous wastes on a routine basis as outlined by Karstensen (2008a, 2009a):

(a) Compliance with all required national/local licenses, permits, authorisations and emissions and relevant national and local regulations as outlined under Environmental Quality Act 1974 and all related Regulations, Orders and Rules under the Act.

(b) Suitable location, technical infrastructure, storage and processing equipment

(c) Reliable and adequate power and water supply

(d) Application of BAT for air emissions pollution prevention and control, along with continuous emission monitoring to ensure compliance with regulation and permits (verified through regular baseline monitoring)

(e) Exit gas conditioning/cooling and low temperatures (< 200°C) in the air pollution control device to prevent dioxin formation

(f) Clear management and organisational structure with unambiguous responsibilities, reporting lines and feedback mechanism

(g) Qualified and skilled employees to manage wastes and health, safety and environmental issues

(h) Adequate emergency and safety equipment and procedures, and regular training

(i) Authorised and licensed collection, transport and handling of hazardous wastes

(j) Safe and sound receiving, storage and feeding of hazardous wastes

(k) Access to an adequate laboratory facilities and equipment for hazardous waste acceptance and feeding control

(l) Adequate record keeping of wastes and emissions

(m) Adequate product quality control routines

(n) Implementation of an environmental management system (EMS) including a continuous improvement programme and ISO 14000 certification

(o) Independent audits (government sanctioned or otherwise), emission monitoring and reporting

(p) Stakeholder dialogues with local community and authorities, and mechanisms for responding to comments and complaints

(q) Open disclosure of performance and compliance verification reports on a regular basis

9.2 Requirements Under Environmental Quality Acts 1974 For Cement Factory Implementing Co-Processing

9.2.1 All cement plant implementing co-processing of scheduled wastes as alternative raw material, alternative fuel or cement additive shall be licenced by the Department of Enviroment as off-site treatment facilities as specified in Order 3(b), Environmental Quality (Prescribed Premises) (Scheduled Wastes Treatment and Disposal Faciities, 1989.

9.3 Emission Limits

9.3.1 Emission limits for cement plant implementing co-processing of scheduled wastes are as below:

NO.	PARAMETER		LIMIT
1	Dust	-	**50 mg/Nm^3**
2	Sulphur dioxide	SO_2	**400 mg/ Nm^3**
3	Nitrogen Oxides	NO_2	**800 mg/ Nm^3**
4	Hydrogen Chloride	HCl	**10 mg/ Nm^3**
5	Volatile Organic Compound	TOC	**20 mg/ Nm^3**
6	Chlorine	Cl_2	**200 mg/ Nm^3**
7	Mercury	Hg	**0.05 mg/ Nm^3**
8	Cadmium	Cd	**<0.05 mg/ Nm^3**
9	Thallium	Tl	
10	Arsenic	As	**Total 2.5 mg/ Nm^3**
11	Cobalt	Co	
12	Lead	Pb	
13	Copper	Cu	
14	Antimony	Sb	
15	Chromium	Cr	

16	Nickel	Ni	
17	Vanadium	V	
18	Manganese	Mn	
19	Zinc	Zn	**100 mg/ Nm^3**
20	Hydrogen Floride	HF	**1 mg/ Nm^3**
21	Dioxin & Furan	D&F	**0.1ng/ Nm^3**
22	Smoke (Ringelmann chart)	-	**No 1**
23	Ammonia & ammonia compound	NH3	**30 mg/ Nm^3**
24	Benzene	-	**5 mg/ Nm^3**

Table 6: Emissions limit for cement plant implementing co-processing of scheduled wastes

9.3.2 The emission limits in Table 6 applicable to the following cement plant:

(a) New or existing cement plant implementing co-processing for the first time;

(b) For existing cement plant which has been licenced to co-process scheduled wastes shall comply to the emission limits as stipulated in the conditions of the licence. However, the cement plant shall upgrade their air pollution control system and make necessary improvement to comply to the new emission limit after year 2019.

9.4 Application procedure

9.4.1 In order to implement co-processing of scheduled wastes, the cement plant shall initially obtain the following approvals from Department of Environment State Office:

(a) For existing cement plant has been in operation before 1987, a new EIA report shall be submitted to the DOE for co-processing activity subject to the prescribed activity under activity 18(a)(ii) of the Environmental Quality (Prescribed Activities) (Environmental Impact Assessment) 1987;

(b) For the expansion of existing cement plant involves an increase in capacity of more than 50% and the process of co-processing, a new Detailed EIA report shall be submitted to the DOE for consideration;

(c) Written approval under Section 19 of the Environmental Quality Act 1974; and

(d) Licence as off-site treatment facility under Section 18 of the Environmental Quality Act 1974.

9.4.2 As a licenced premis of an off-site treatment facility, any proposal to receive new code or new source of scheduled wastes to be co-processed, the cement plant shall require a few step approval from the Department of Environment (DOE) as below:

(a) Co-processing activities are believed to have effects residue. Therefore, all cement plant shall submit additional information(addendum) to DOE together with other information required during the process of In Principle Approval for the usage, increasing the quantity and types of wastes being allowed;

(b) The addendum should detail the types of scheduled wastes that will be used and reviewing the effectiveness of pollution control system to ensure the use of scheduled wastes do not effect on the environment especially the sensitive receptor;

(c) The Addendum is required as a basis for considering the use of scheduled wastes as well as to allow amendments to the conditions of approval of the EIA made by referring to the relevant provisions of information on raw materials including cumulative raw materials

(d) In Principle Approval from Department of Environment Headquarters. Assessment will be carried out to study the suitability of the scheduled wastes to be used as alternative raw material, alternative fuel or cement additive;

(b) Operational approval from Department of Environment State Office. This will also require amendment to the licence condition to include new code or new source scheduled wastes for existing code in the licence.

ANNEX 1
Clinker Production Process

ANNEX 1 - CLINKER PRODUCTION PROCESS

A. Introduction

1. Cement production involves the heating, calcining and sintering of a carefully proportioned mixture of calcareous and argillaceous materials, usually limestone and clay, to produce cement clinker, which is then cooled and ground with additives such as gypsum (a setting retardant) to make cement. This process typically requires approximately 2.9 to 6.7 GJ of energy depending on the kiln technology employed (IEA, 2007) and 1.5 to 1.7 tonnes of raw materials per tonne of clinker produced (Szabó et al, 2003); the portion of raw material that does not become clinker is either lost on ignition or becomes CKD (U.S. EPA, 1993). 'Wet' processes also use water to make the raw slurry that feeds the kilns; about 600 kg of water is used in the manufacture of one tonne of cement, some of which is returned to the environment (EA, 2005).

2. Manufacturers use clinker and specific constituents in various proportions to produce cements that meet different physical and chemical requirements for specific applications. By far the most common hydraulic cements in use today are either Portland cements or 'blended' cements (van Oss and Padovani, 2003). The standard specifications with which Portland cements must comply are similar (albeit not identical) in all countries and various names are used to define the material. Blended cements, also called composite cements, are mixtures of Portland cement with one or more pozzolanic additives or extenders (sometimes collectively termed 'supplementary cementitious materials'), such as pozzolana (volcanic ashes), certain types of fly ash (from coal-fired powerplants), granulated blast furnace slag, silica fume, or limestone. These materials commonly make up about 5 to 30 per cent by weight of the total blend, but can be higher (van Oss, 2005). The designations for blended cements differ worldwide.

3. Although a variety of cement types are produced worldwide, cement production follows essentially the same process, as described below.

B. Conventional raw materials and fuel

4. The raw materials for cement must yield the oxides required for clinker in the approximate proportions noted in **Table 1A**, with the major requirement being calcium oxide (CaO). In practical terms this means that naturally occurring calcareous deposits, such as limestone, marl or chalk, which consist essentially of calcium carbonate ($CaCO_3$), are required. Clay or shale typically provides the remaining components. To correct for minor deficiencies in one or more oxides in the primary raw materials, 'corrective' constituents[1] such as iron ore, bauxite or sand, may be added to adapt the chemical composition of the raw mix to the requirements of the process and product specifications (Taylor, 1997; Karstensen, 2007b). Generally, most, but not all, of the raw materials are mined adjacent to or within a few miles of the cement plant.

1 Sometimes called "accessory" or 'sweetener' materials (van Oss, 2005).

Table 1A - Chemical composition of ordinary Portland cement clinker and conventional raw materials

Constituent	Clinker	Limestone, lime marl, chalk	Clay	Sand	Iron ore	Bauxite
SiO_2	19.71-24.25%	0.5-50%	33-78%	80-99%	4-11%	2.9%
Al_2O_3	3.76-6.78%	0.1-20%	7-30%	0.5-7%		
TiO_2	0.21-0.52%	0.0-0.7%	0.2-1.8%	0.0-0.5%		
$Al_2O_3 + TiO_2$			7-30%	0.5-2%	0.2-3%	57.5%
Fe_2O_3	1.29-4.64%	0.2-5.9%	4.0-15%	0.0-4%		
Mn_2O_3	0.03-0.68%	0.02-0.15%	0.09%	0.051%		
$Fe_2O_3 + Mn_2O_3$		0.1-10%	2-15%	0.5-2%	19-95%	22.8%
CaO	63.76-70.14%	20-55%	0.2-25%	0.1-3%	0.1-34%	2.4%
MgO	0.00-4.51%	0.2-6%	0.3-5%	0.3-0.5%	≤1.5%	0.04%
K_2O	0.31-1.76%	0-3.5%	0.4-5%	0.2-3%	Traces	0.04%
Na_2O	0.03-0.335	0.0-1.5%	0.1-1.5%	0.0-1%	Traces	0.02%
Cl		0.0-0.6%	0.0-1%	Traces		
P_2O_5	0.02-0.27%	0.0-0.8%	0.0-1.0%	0.0-0.1%		
Loss on ignition ($CO_2 + H_2O$)	0.09-1.56%	2-44%	1-20%	≤5	0.1-30%	13.5%

Sources: EIPPCB (2010) and CEMBUREAU (1999)

5. Natural forms of $CaCO_3$ consist of coarser or finer crystals of calcite. Limestone is microcrystalline $CaCO_3$ with clay as the main impurity. Chalk is a very fine grained, porous marine limestone composed almost entirely of microscopic fossils. The main constituents of shale and clay are clay minerals, finely divided quartz and, sometimes, iron oxides. Traditionally, wet materials (chalk and clay) have been used in 'wet' or 'semi-wet' kiln processes, and dry materials (limestone) have been used in the 'dry' or 'semi-dry' processes (EA, 2005).

6. Around 80-90 % of raw material for the kiln feed is limestone; clayey raw material accounts for between 10-15 %, although the precise amounts will vary (BGS, 2005). In addition to the chemical composition of the desired product, the proportion of each type of raw material used in a given cement kiln will depend on the composition of the specific materials available to the operator, which is tested on a regular basis.

7. The proportioning process takes into account the ratios of calcium, silica (SiO_2), alumina (Al_2O_3), and iron oxide (Fe_2O_3) needed to produce good quality clinker, as well as the 'burnability' of the raw mix (i.e., the requirements in terms of time, temperature, and fuel to process the material) (U.S. EPA, 1993). In addition, kiln operators pay close attention to the presence of 'impurities' in the mixture, including magnesia, sulphur, chlorides, and oxides of potassium and sodium (referred to as 'alkalies'). Magnesia (MgO) can be desirable to some extent because it acts as a flux at sintering temperatures, facilitating the burning process, however MgO levels are carefully monitored because they can lead to the production of clinker that is unsound if not cooled rapidly[2]. Alkalies can react in the cool end of the kiln with sulphur dioxide, chlorides, and carbon dioxide contained in the kiln gas and can lead to operational problems (U.S. EPA, 1993).

8. The raw materials used in the cement production process naturally contain metals and halogens. Thus, antimony, arsenic, barium, beryllium, cadmium, chromium, lead, mercury, nickel, selenium, silver, thallium, vanadium, zinc, bromine, chlorine, fluorine, and iodine are typically present in the raw materials. The amounts of these components depend on the geological formations from which the raw materials are mined. In addition to the metals and halogens present, the raw materials can contain organic compounds (Mantus, 1992). Average values and range of concentrations of these constituents are presented in **Table 1B**.

9. Cement production also has high energy requirements, which typically account for 30-40 % of the production costs (excluding capital costs). Most cement kilns today use coal and petroleum coke as primary fuels, and to a lesser extent, natural gas and fuel oil. As well as providing energy, some of these fuels, especially coal or lignite, produce significant quantities of ash similar in composition to the argillaceous component.

10. Many plants routinely burn more than one fuel. For example, when firing up a cold kiln, natural gas or fuel oil is commonly used for the slow, warm-up phase necessary to prevent thermal overstressing of the kiln's refractory brick lining. Once the kiln is sufficiently hot, it will be switched over to coal and/or coke (generally petroleum coke) for production operations. (van Oss, 2005)

11. Coal can contain significant quantities of sulphur, trace metals, and halogens, and their concentrations are dependent on the area in which the coal was mined. The typical concentration of trace elements in the primary fuels is as in **Table 1C**. Sulphur (in the form of SO_3) will vaporize in the kiln to form sulphur dioxide (SO_2), and condense in the form of sulphates. Within the kiln, these sulphates combine

2 Such clinker used to make concrete can cause destructive expansion of hardened concrete through slow reaction with water.

with calcium and potassium, causing operational problems in the cool end of the kiln. Halogens are of concern because chlorides can cause operational problems similar to those caused by sulphur. Chlorine concentrations in coal can range from 100 to 2800 parts per million. (U.S. EPA, 1993)

12. Both heat and electricity consumption vary significantly with kiln technology as presented in **Table 1D** and, for the same general technology, plants operating multiple kilns tend to have higher energy requirement per tonne of overall output capacity than the plants with the same overall capacity that operate a single kiln. Wet kilns consume more fuel on a unit basis than the dry kilns because of the need to evaporate the water in the slurry feed and the much larger size of the wet kilns. (van Oss, 2005).

Table 1B - Trace element concentrations (in parts per million) in conventional raw materials (Min = minimum value; Max = maximum value; AV = average value; n.a. = no data available)

Constituent	Limestone Min-Max (AV)	Marl Min-Max (AV)	Clay Min-Max (AV)	Sand Min-Max (AV)	Iron ore Min-Max (AV)	Gypsum/anhydrite Min-Max (AV)
As	0.1-15 (3)	0.2-12 (6)	2-100 (14)	0.4-42 (11)	2-1200 (37)	0.2-3.5 (1.5)
Be	0.01-12 (0.3)	n.a.-1 (0.5)	1-7 (3)	0.6-1.5 (1.0)	0.8-2 (1)	0.02-0.9 (0.2)
Cd	0.02-2 (0.2)	0.02-0.5 (0.3)	0.01-1 (0.2)	0.01-1 (0.2)	0.02-15 (6)	0.03-2.3 (0.15)
Co	0.1-7 (3)	n.a.-28 (5)	6-25 (20)	0.3-37 (11)	109-183 (144)	0.02-3.9 (1)
Cr	0.5-184 (14)	1.2-71 (28)	15-260 (85)	1-220 (19)	8-1400 (495)	1-27.3 (8.8)
Cu	5-57 (11)	4.9-35 (12)	10-285 (43)	1.2-85 (10)	(1520)	0.3-12.8 (7)
Hg	0.005-0.1 (0.04)	0.005-0.1 (0.03)	0.01-0.5 (0.2)	0.01-1 (0.02)	n.a.-1 (0.5)	0.00625-1.3 (0.1)
Mn	250-3300 (500)	n.a.-3300 (360)	n.a.-2500 (600)	46-2040 (194)	900-1200 (1090)	n.a.
Ni	1.4-131 (18)	1.5-57 (16)	7-236 (63)	1-73 (13)	5-815 (331)	0.3-14.5 (5.5)
Pb	0.27-151 (18)	0.3-57 (12)	1-219(25)	0.7-70 (10)	4-8700 (350)	0.2-20.5 (7)

Sb	0.2-27 (1)	n.a.-27 (4)	0.5-13 (2)	0.3-12 (7)	(26)	0.1-5 (1)
Se	0.4-30 (0.6)	n.a. (1)	n.a.-2.5 (0.5)	n.a. (1)	(8)	0.6-17 (0.8)
Sn	0.9-24 (4)	n.a.-24 (3)	1.6-30 (5)	1.8-40 (3)	n.a.-500 (25)	n.a.
Te	n.a. (0.7)	n.a. (1)	n.a. (0.5)	n.a. (0.5)	n.a.-13 (10)	n.a.
Tl	0.05-3 (0.3)	0.05-0.68 (0.6)	0.1-1.6 (0.5)	0.05-1 (0.2)	0.1-400 (2)	0.1-1.0 (0.3)
V	5-80 (26)	n.a.-49 (20)	30-300 (130)	2-240 (50)	10-690 (256)	1-27.8 (13.5)
Zn	0.1-229 (30)	22-79 (48)	2-304 (78)	4.2-112 (25)	24-9400 (3288)	1-59 (19)
Br a/	n.a. (5.9)	n.a.	1-58	n.a.	n.a.	n.a.
Cl a/	50-240	n.a.	15-450	n.a.	n.a.	n.a.
F a/	100-940	n.a.	300-990	n.a.	n.a.	n.a.
I a/	0.25-0.75	n.a.	0.2-2.2	n.a.	n.a.	n.a.

a/ Mantus (1992)
Source: Achternbosch et al. (2003), unless otherwise noted.

Table 1C - Trace element concentrations (in parts per million) in primary fuels (Min = minimum value; Max = maximum value; n.a. = no data available)

Constituent	Anthracite Min-Max	Bituminous coal Min-Max	Lignite Min-Max	Petroleum coke Min-Max
As	1-200	n.a.	0.1-12	0.2-0.8
Be	0-8	n.a.	0.04-0.6	0.02-0.03
Cd	0.01-10	n.a.	0.06-2.4	0.04-4
Co	0.5-43	n.a.	0.5-4.2	n.a.
Cr	1-260	n.a.	0.9-20	0.9-104
Cu	0.30-60	n.a.	0.4-15	n.a.
Hg	0.01-3	n.a.	0.01-0.7	0.01-0.09
Mn	5-356	n.a.	50-160	n.a.
Ni	1-110	n.a.	0.6-29	24-355
Pb	5-270	n.a.	0.7-34	1-102
Sb	0.05-5	n.a.	0.04-2.5	n.a.
Se	0-6	n.a.	0.4-25	n.a.
Sn	1.3-7.8	n.a.	0.5-15	n.a.
Te	0.2-5.0	n.a.	0.1-10	n.a.
Tl	0.1-5	n.a.	0.05-0.4	0.04-3.1
V	10-250	n.a.	0.1-84	45-1435
Zn	4.5-405	n.a.	1-70	16-220
Br a/	n.a.	7-11	n.a.	n.a.
Cl a/	n.a.	100-2800	n.a.	n.a.
F a/	n.a.	50-370	n.a.	n.a.
I a/	n.a.	0.8-11.2	n.a.	n.a.

a/ Mantus (1992)
Source: Achternbosch et al. (2003), unless otherwise noted.

Table 1D - Energy requirements for clinker manufacture

Process	Fuel consumption, GJ/tonne
Vertical shaft kiln	3.7-6.6
Wet process	5.9-6.7
Long dry process	4.6
1 stage cyclone preheater	4.2
2 stage cyclone preheater	3.8
4 stage cyclone preheater	3.3
4 stage preheater + precalciner	3.1
5 stage preheater + precalciner	3.0-3.1
6 stage preheater + precalciner	2.9

Source: IEA (2007) and Szabó (2003)

C. Manufacturing process

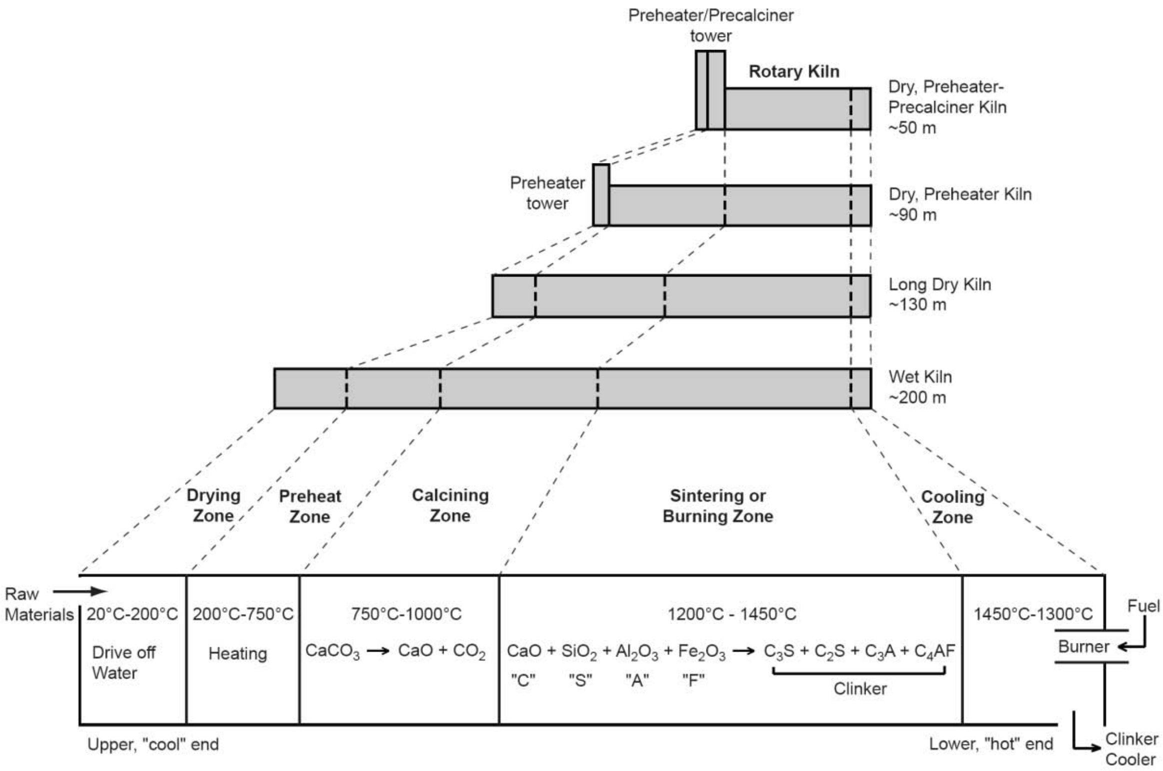
13. Portland cement production begins with the manufacture of clinker followed by its fine grinding with gypsum and other additives to make the finished cement product. Grinding can occur on site or at offsite grinding plants known as cement mills. Clinker manufacture involves the quarrying, crushing, and proportioning of raw materials to produce either a raw meal for the dry and semi-dry processes or a slurry for the wet and semi-wet processes. Once the material is prepared, the raw mix is fed into a kiln where it is heated as it moves through a number of chemical and physical processes necessary for forming the clinker.

14. In the kiln, the raw meal, or slurry in the wet process, is subjected to a thermal treatment process consisting of the consecutive steps of 'drying/preheating', 'calcining', and 'sintering' (also known as 'burning' or 'clinkering'); the various reactions zones are depicted in **Figure 1A**.

15. The first drying and preheating zone, occurs in a temperature range of from <100 to 750°C. Here, residual or free water is evaporated from the raw meal feed, the clay materials begin to decompose and the bound water is removed so that they become dehydrated. Next is the calcining zone, where materials temperatures range from 750 to 1000°C. The material is 'calcined', where the calcium carbonate ($CaCO_3$) in the limestone is dissociated producing calcium oxide (CaO, lime) and liberating carbon dioxide (CO_2) gas.

16. Finally, in the burning zone, calcium oxide reacts with silicates, iron, and aluminium to form dicalcium silicate, tricalcium silicate, tricalcium aluminate, and tetracalcium aluminoferrite, denoted in shorthand as C_2S, C_3S, C_3A, and C_4AF respectively. In addition, clinker nodules, typically 3 to 20 mm in diameter, are formed in a semi-solid state in the burning zone, and solidify completely on cooling, which begins in a short cooling zone within the kiln, and continues in a cooler, outside of the cement kiln.

Figure 1A - Diagram of 'reaction' zones for different kiln technologies



Source: van Oss (2005)

17. In the clinker burning process, it is essential to maintain kiln charge temperatures in the sintering zone between 1400 and 1500°C to convert the raw meal to clinker. To reach these temperatures, flame temperatures of about 2000°C are necessary. Also, for reasons of clinker quality, excess air is required in the sintering zone to maintain oxidizing conditions. Otherwise, if insufficient oxygen is present, tetracalcium alumino ferrite does not form; instead Fe_2O_3 is reduced to FeO. This leads to a clinker product that produces a quick setting cement with decreased final strength. Additionally, the presence of unburned carbon in the burning region produces a clinker with an undesirable brown colour. (U.S. EPA, 2004)

18. The composition of the clinker, as well as the names and formulas of the clinker components are listed in **Table 1E**.

19. To complete the production of Portland cement, the cooled clinker is ground with a small amount of gypsum or anhydrite. **Figure 1 Figure 2** in the main Guidelines provides a process flow diagram of the general cement manufacturing process.

Table 1E - Typical mineralogical composition of ordinary Portland cement clinker

Chemical name (common name)	Chemical formula	Common notation a/	Concentration range
Tricalcium silicate ('alite')	Ca_3SiO_5	C_3S	50-70%

Dicalcium silicate ('belite')	Ca_2SiO_4	C_2S	15-30%
Tricalcium aluminate ('aluminate')	$Ca_3Al_2O_6$	C_3A	5-10%
Tetracalcium aluminoferrite ('ferrite')	$Ca_4Al_2Fe_2O_{10}$	C_4AF	5-15%

a/ Abbreviations: C=CaO; S=SiO_2; A=Al_2O_3; F=Fe_2O_3
Source: Taylor (1997)

20. Clinker can be made either in energy-intensive and small-scale vertical kilns or in more efficient, larger scale rotary kilns. With the exception of vertical shaft kilns (VSK) still used in certain geographical areas (mainly China and India) (CPCB, 2007; Höhne and Ellermann, 2008), cement clinker is predominantly burnt in rotary kilns. For the manufacture of cement using rotary kilns, heating of the raw meal to produce cement clinker can take place in one of four different types of arrangements: the 'dry', 'semi-dry', 'semi-wet', or 'wet' processes (EIPPCB, 2010; UNEP, 2007):

(a) Dry process: Dry raw meal is fed to a cyclone preheater or precalciner kiln or, in some cases, to a long dry kiln with internal chain preheater.
(b) Semi-dry process: Dry raw meal is pelletised with water and fed to a travelling grate preheater prior to the rotary kiln or in some cases, to a long kiln equipped with internal cross preheaters.
(c) Semi-wet process: Raw slurry is first dewatered in filter presses. The resulting filter cake is either extruded into pellets and fed to a travelling grate preheater or fed directly to a filter cake drier for (dry) raw meal production prior to a preheater/precalciner kiln.
(d) Wet process: The raw slurry is fed either directly to a long rotary kiln equipped with an internal drying/preheating system (conventional wet process) or to slurry drier prior to a preheater/precalciner kiln (modern wet process).

21. In China, approximately 60 % of the cement was produced in 2005 in VSKs, an amount that is expected to drop to 50 % by 2015 (Karstensen, 2006a). In Europe, about 90 % of the cement production is from dry process kilns, a further 7.5 % of production is accounted for by semi-dry and semi-wet process kilns, with the remainder of European production, about 2.5 per cent, coming from wet process kilns (EIPPCB, 2010). In the United States, no new wet kilns have been built since 1975, and approximately 80 % of U.S. cement production capacity now relies on the dry process technology (U.S. E P A, 2007). The wet process remains dominant in the former Soviet Union and Australia/New Zealand and is still significant in Canada, India, Latin America and Africa (Watson et al., 2005). **Table 1F** provides the share mix of kiln technologies in each region or country in 2002.

Table 1F - Share of different kiln types in 2002

Regions, Countries		Kiln Type (% Production)			
		Dry	Semi-Dry	Wet	Vertical
North America	United States	65	2	33	0
	Canada	71	6	23	0
Western Europe		58	23	13	6
Eastern Europe	Former Soviet Union	12	3	78	7
	Other Eastern Europe	54	7	39	0
Asia	Japan	100	0	0	0
	Australia and New Zealand	24	3	72	0
	China	5	0	2	93
	South East Asia	80	9	10	1
	Republic of Korea	93	0	7	0
	India	50	9	25	16
Latin America		67	9	23	1
Africa		66	9	24	0
Middle East		82	3	16	0

Source: Baron et al. (2007)

22. Although VSKs are improvements over the old, chimney-type kilns in that some VSKs allow for continuous processing, they are considered to be less energy efficient than the rotary kilns, and VSK clinker (and hence cement) is generally considered to be of lower quality (van Oss, 2005). Furthermore, many VSKs plants have virtually no environmental controls in place, and the nature of the technology precludes effective use of modern dust (and other emission) controls. Compared with preheater/precalciner kilns, VSKs seems to consume from 14 to 105 % more coal per tonne of clinker; fuel substitution is however not feasible for vertical shaft kilns (Karstensen, 2006a). The raw materials used for cement production in VSKs are exactly the same as in any other production process; corrective materials may also be required to adjust the chemical composition of the raw mix.

ANNEX 2

QUALITY ASSURANCE AND QUALITY CONTROL PROGRAM IN THE IMPLEMENTATION OF CO-PROCESSING IN CEMENT PLANT

ANNEX 2 – QUALITY ASSURANCE AND QUALITY CONTROL PROGRAM IN THE IMPLEMENTATION OF CO-PROCESSING IN CEMENT PLANT

1. A comprehensive programme for quality assurance (QA) and quality control (QC) should be applied. The aim is to ensure that the product meets standard specifications, plant operations are not negatively affected by the use of hazardous wastes, environmental protection and to reduce health and safety risks. QA is necessary for ensuring that all data and the decisions resulting from that data are technically sound, statistically valid, and properly documented.

2. A QA plan should be prepared to help ensure that the monitoring, sampling, and analytical data meet specific objectives for precision, accuracy, and completeness and to provide the framework for evaluating data quality. The plan should cover waste streams and product materials handled at the facility with detailed instructions for the following:

   (a) Organization and responsibilities;
   (b) QA objectives for data measurement of precision, accuracy, completeness, representativeness, and comparability;
   (c) Sampling procedures;
   (d) Sample handling and custody;
   (e) Analytical procedures;
   (f) QC checks (blanks, spikes, replicates, etc.) and frequency;
   (g) Instrument/equipment testing, inspection, or maintenance;
   (h) Instrument/equipment calibration procedures and frequency;
   (i) Data review, verification, validation, and reporting.

3. Adequate laboratory design, infrastructure, equipment, and instrumentation should be provided and maintained to ensure that all required analysis are completed in a timely manner. Periodic tests of the laboratory should be considered to evaluate and improve performance.

4. Safety and health should be taken into consideration when conducting sampling. Employees carrying out sampling require training for the hazards associated with waste, handling procedures, protective clothing and equipment. Those involved in sampling activities should be fully aware of applicable QA/QC procedures.

5. BAT for waste quality control in cement manufacturing processes is outlined by the EIPPCB (2010):

   (a) To apply QA systems to guarantee the characteristics of wastes and to analyse any waste that is to be used as raw material and/or fuel in a cement kiln for: maintenance of quality over time; physical criteria, for example, emissions formation, coarseness, reactivity, burnability, calorific value; chemical criteria, for example, chlorine, sulphur, alkali and phosphate content and relevant metals content;

   (b) To control the amount of relevant parameters for any waste that is to be used as raw material and/or fuel in a cement kiln, such as chlorine, relevant metals (for example, cadmium, mercury, thallium), sulphur, total halogen content;

(c) To apply QA systems for each waste load.

6. Internal audits should be carried out with a frequency that ensures QA/QC procedures are in use and that personnel conform to them. Independent third party audits should be conducted at least annually or as required to determine the effectiveness of the implemented quality system. Audit reports should be submitted to management with requirements to correct observed deficiencies.

ANNEX 3

HEALTH AND SAFETY ASPECTS

ANNEX 3 – HEALTH AND SAFETY ASPECTS

1. Health and safety should be a conscious priority and integrated into all aspects of operations during hazardous waste management. Overall and specific personnel requirements, the chain of command, and individual roles and responsibilities, should be clearly established.

2. A health and safety programme should be designed to identify, evaluate, and control safety and health hazards, and provide for emergency response for hazardous waste operations. The content and extent of this programme should be proportionate to the types and degrees of hazards and risks associated with specific operations.

3. Adequate documentation and information on safe hazardous waste handling, operating procedures and contingency measures should be available. Through openness and transparency, facility management should ensure the workforce is fully informed about health and safety measures and standards. Easily understood safety and emergency instructions should be provided to employees and contractors in advance.

4. In the EU, the BAT includes the appliance of hazardous waste safety management to the handling, storage, and the feeding of hazardous waste materials. For example, using a risk based approach according to the source and type of waste, for the labelling, checking, sampling and testing of waste to be handled. (EIPPCB, 2010)

Hazard analysis

5. Hazards and potential exposures should be determined and appropriate controls should be in place to maintain employee health and safety. Hazards requiring the use of personal protective equipment (PPE) should be identified. Assessments such as job hazard analysis (JHA), job safety analysis (JSA), safety analysis reports (SAR), process hazard analysis (PHA), and job, task, and hazard analysis (JTHA), are recommended.

Access and hazard control

6. To eliminate or control worker exposure to hazards, the following should be considered in order of preference:

   (a) Engineering controls to preclude worker exposure by removing or isolating the hazard. For example, ventilation or use of remotely operated material handling equipment;

   (b) Administrative controls to manage worker access to hazards and establish safe working procedures. For example, security measures to prevent unauthorized or unprotected access to hazardous wastes on-site;

   (c) PPE, when engineering or administrative controls are not feasible or do not totally eliminate the hazard.

7. These controls are designed to reduce and maintain employee exposure below national occupational exposure limit values. If these are not available, internationally recognized exposure levels should be considered.

8. Examples include: the Threshold Limit Value (TLV) occupational exposure guidelines by the American Conference of Governmental Industrial Hygienists (ACGIH); the Pocket Guide to Chemical Hazards by the United States National Institute for Occupational Health and Safety (NIOSH); Permissible Exposure Limits (PELs) by the Occupational Safety and Health Administration of the United States (OSHA); Indicative Occupational Exposure Limit Values (IOELVs) by European Union member states, or other similar sources.

9. For hazardous substances and health hazards for which there are no permissible or applicable exposure limits, the operators could use the published literature and material safety data sheets (MSDS) as a guide to determine an appropriate level of protection.

Personal protective equipment

10. Employees, contractors and visitors to an installation should be provided with PPE where engineering control methods are not feasible to reduce exposure to permissible exposure limits. PPE should be selected to protect against any present or potential hazard and appropriate to the task-specific conditions and duration.

11. All personnel involved in hazardous waste operations should be fully aware of: equipment selection and use, maintenance and storage, decontamination and disposal, training and proper fit, donning and doffing procedures, inspection, in-use monitoring, programme evaluation, and equipment limitations.

Training

12. Employees should be effectively trained to a level determined by their job function and responsibility. This should be carried out prior to them being permitted to engaging in hazardous waste operations that could expose them to hazardous substances, safety, or health hazards. Training activities should be adequately monitored and documented in terms of curriculum, duration, and participants.

13. The training should cover safety, health and other hazards present on the facility; use of personal protective equipment; work practices to minimize risks from hazards; safe use of engineering controls and equipment on the site; medical surveillance, including recognition of symptoms and signs that could indicate over exposure to hazards. Those engaged in hazardous emergency response should also be appropriately trained.

Medical surveillance

14. A medical monitoring programme should be implemented to assess and monitor employee health both prior and during employment. An effective programme should consider the following components as a minimum:

(a) Pre-employment screening, to determine fitness-for-duty, including the ability to work while wearing PPE, and provide baseline data for future exposures;

(b) Periodic medical monitoring examinations (the content and frequency of which depend on the nature of the work and exposure), to determine biological trends that may mark early signs of chronic adverse health effects;

(c) Provisions for emergency and acute non-emergency treatments.

Emergency response

15. Emergency plans and procedures should be established for the protection of the workforce and public before hazardous waste operations begin. An Emergency Response Plan, ensuring appropriate measures to handle possible on-site emergencies and coordinate off-site response, should be in place. As a minimum, this plan should address the following:

(a) Pre-emergency planning and coordination with outside emergency responders;
(b) Personnel roles, lines of authority, training and communication procedures;
(c) Emergency recognition and prevention procedures;
(d) Safe distances and places of refuge;
(e) Site security and control procedures;
(f) Evacuation routes and procedures;
(g) Site mapping highlighting hazardous areas, site terrain, site accessibility and off-site populations or environments at potential risk;
(h) Decontamination procedures;
(i) Emergency medical treatment and first aid procedures;
(j) Personal protective and emergency equipment at the facility;
(k) Emergency alerting and response procedures;
(l) Documenting and reporting to local authorities;
(m) Critique of response and follow-up procedures.

16. Emergency equipment, such as fire extinguishers, self-contained breathing apparatus, sorbents and spill kits, and shower/eye wash stations should be located in the immediate vicinity of hazardous waste storage and processing areas.

17. The Plan procedures should be rehearsed regularly using drills and mock situations, and reviewed periodically in response to new or changing conditions or information.

18. Arrangements should be made to familiarize local authorities and emergency responders with the layout of the facility; properties of hazardous waste handled at the facility and associated hazards; places where facility personnel would normally be working; facility entrances and possible evacuation routes. Arrangements agreed to by local authorities, hospitals and emergency response teams should be described in the Emergency Response Plan.

ANNEX 4

COMMUNICATIONS AND STAKEHOLDER INVOLVEMENT

ANNEX 4 – COMMUNICATIONS AND STAKEHOLDER INVOLVEMENT

1. Stakeholders are those who see themselves as potentially affected by the operations of a facility. These can be individuals and groups on a local, national, or international scale and include neighbours, community organizations, employees, trade unions, government agencies, the media, non-governmental organizations, contractors, suppliers and investors.

2. Public communication is the providing of information through media sources, including brochures, websites, newspapers, radio and television. Stakeholder involvement is concerned with community members and others with an interest in the facility, through public meetings, presentations, advisory committees, and personal approaches. Both should form part of the normal operations of a plant.

3. Facilities should have clear objectives for working with stakeholders. This includes a realistic timescale for engagement, committing necessary resources and a willingness to find mutually beneficial outcomes.

4. Operators and regulatory authorities should be prepared to address public concerns over possible impacts of co-processing and strive to establish efficient communication methods to explain the activities. Operators planning on using hazardous waste should provide all necessary information to allow stakeholders to understand the use of the wastes in the cement kiln while illustrating the measures that would be implemented to avoid adverse impacts.

ANNEX 5

GENERAL RECOMMENDATION ON WASTE ACCEPTANCE AND PRE-PROCESSING OF HAZARDOUS WASTE FOR CO-PROCESSING

ANNEX 5 – GENERAL RECOMMENDATION ON WASTE ACCEPTANCE AND PRE-PROCESSING OF HAZARDOUS WASTE FOR CO-PROCESSING

WASTE ACCEPTANCE

1. Prior knowledge of wastes is necessary to ensure that the waste falls within the requirements of the facility's permit and will not adversely affect the process. Generators of hazardous waste should in most circumstances know the composition, nature and problems associated with their waste, ensuring that all relevant information is passed to those involved in its subsequent management.

2. Hazardous and non hazardous waste acceptance comprises two stages: pre-acceptance (or screening) and on-site acceptance. Pre-acceptance involves the provision of information and representative samples of the waste to allow operators to determine suitability before arrangements are in place for acceptance. The second stage concerns procedures when the waste arrives at the facility to confirm previously approved characteristics.

3. Failure to adequately screen waste samples prior to acceptance and a confirmation of its composition on arrival at the installation may lead to subsequent problems. Inappropriate storage, mixing of incompatible substances, and accumulation of wastes could occur.

<u>Pre-acceptance</u>

4. A pre-acceptance, or pre-shipment screening, protocol should ensure that only properly and safely handled hazardous waste streams are approved for shipment to the facility. Such protocol is necessary to:

   (a) Ensure regulatory compliance by screening out unsuitable wastes;
   (b) Confirm the details relating to composition, and identify verification parameters that can be used to test waste arriving at the facility;
   (c) Identify any substances within the waste that may affect its processing, or react with other reagents;
   (d) Accurately define the range of hazards exhibited by the waste.

5. The operator should obtain information on the nature of the process producing the waste, including its variability. Other required descriptions include: composition (chemicals present and individual concentrations); handling requirements and associated hazards; the quantity and the form of waste (solid, liquid, sludge etc); sample storage and preservation techniques. Ideally, information should be provided by the waste generators . Alternatively a system for the verification of the information provided by any intermediaries should be considered.

6. Systems for the provision and analysis of waste representative samples should be in place. The waste sample should be taken by a competent technician and the analysis carried out by a laboratory, preferably accredited with robust QA/QC methods and record keeping and a chain-of-custody procedure should be

considered. The operator should carry out a comprehensive characterisation (profiling) and testing with regard to the planned processing for each new waste. No waste should be accepted without sampling and testing being carried out. The exception is unused, outdated or off-specification uncontaminated products that have appropriate MSDS or product data sheets.

7. A Waste Analysis Plan (WAP) should be prepared and maintained to document procedures used to obtain a representative waste sample and to conduct a detailed chemical and physical analysis. A WAP should address measures used to identify potentially reactive and incompatible wastes. It should include testing of a representative sample to qualify the waste for use at the facility (pre-acceptance) and to verify its constituents (acceptance). Further testing of samples taken during or after waste pre-processing or blending should be used to verify the quality of the resultant stream.

8. Operators should ensure that the technical appraisal is carried out by qualified, experienced staff who understands the capabilities of the facility.

9. Records of pre-acceptance should be maintained at the facility for cross-referencing and verification at the waste acceptance stage. Information should be recorded and referenced, available at all times, regularly reviewed and kept up to date with any changes to the waste stream.

On-site acceptance

10. On-site verification and testing should confirm waste characteristics with the pre-acceptance information. Acceptance procedures should address:

(a) Pre-approved wastes arriving on-site, such as a pre-booking system to ensure that sufficient capacity is available
(b) Traffic control;
(c) Check for documents arriving with the load;
(d) Load inspection, sampling and testing;
(e) Rejection of wastes and the discrepancy reporting procedures;
(f) Record keeping;
(g) Periodic review of pre-acceptance information.

11. Wastes should not be accepted without detailed written information identifying the source, composition and hazard levels.

12. Where facilities provide an emergency service such as the removal of spillages or fly-tipped hazardous wastes, there may be situations where the operator is unable to adhere to established pre-acceptance and/or acceptance procedures. In such instances, the operator should communicate the occurrence to the competent authorities immediately.

Arrival

13. If sufficient storage capacity exists and the site is adequately manned, suitably qualified and trained personnel should supervise the receiving of hazardous wastes. All wastes received should be treated as unknown and hazardous until compliance with specifications has been positively verified.

14. A suitable description should accompany hazardous waste delivery including: name and address of the generator; name and address of the transporter; waste classification and description; volume and weight; and hazardous characteristics of the waste.

15. Documentation accompanying the shipment should be reviewed and approved, including the hazardous waste manifest, if applicable. Any discrepancies should be resolved before the waste is accepted. If they cannot be resolved, the waste should be rejected and sent back to the original generator, or at its request, to an alternate facility.

16. Where possible, waste loads should be visually inspected. All containers should be clearly labelled in accordance with applicable regulations for the transport of dangerous goods and checked to confirm quantities against accompanying documentation. They should be equipped with well-fitting lids, caps and valves secure and in place and inspected for leaks, holes, and rust. Any damaged, corroded or unlabelled container or drum should be classified as 'non-conforming' and dealt with appropriately.

17. All incoming loads should be weighed, unless alternative reliable volumetric systems linked to specific gravity data are available.

Inspection

18. Wastes should only be accepted at the facility after thorough inspection. Reliance solely on supplied written information should not be acceptable. Physical verification and analytical confirmation should be undertaken to ensure the waste meets permit specifications and regulatory requirements. All wastes, whether for processing or storage, should be sampled and undergo verification and testing, according to the frequency and protocol defined in the WAP, except for unused, outdated, off-specification or uncontaminated products.

19. On-site verification and testing should take place to confirm:

(a) The identity and description of the waste;
(b) Consistency with pre-acceptance information;
(c) Compliance with the facility permit.

20. Techniques for inspection vary from simple visual assessment to full chemical analysis. The extent of the procedures adopted will depend upon waste chemical and physical composition and variation; known difficulties with certain waste types or of a certain origin; specific sensitivities of the installation concerned (for example, certain substances known to cause operational difficulties); and the existence or absence of a quality controlled specification for the waste, among others. (Karstensen, 2008a)

21. The facility should have a designated sampling or reception area where containerised waste is unloaded if adequate space is available and temporarily stored for further sampling and sample analysis. Wastes should be segregated immediately to remove possible hazards due to incompatibility. Sampling should ideally take place within 24 hours of unloading. During this period, hazardous

wastes should not be bulked, blended or otherwise mixed. Bulk wastes should be inspected and accepted for processing prior to unloading.

22. Sampling should comply with specific national legislation, where it exists, or with international standards. Sampling should be supervised by laboratory staff and in those countries where regulations do not exist, qualified staff should be appointed. Sampling should include well-established procedures such as those developed by the American Society for Testing and Materials (ASTM), the European Committee for Standardization (CEN), and the United States Environmental Protection Agency (EPA). A record of the sampling regime for each load and justification for the selected option should be maintained.

23. Samples should be analysed by a laboratory with a robust QA/QC programme, including but not limited to suitable record keeping and independent assessments. Analysis should be carried out at a timescale required by facility procedures. In the case of hazardous wastes this often requires the laboratory to be on-site.

24. Typically, waste should be sampled and analysed for a few key chemical and physical parameters (fingerprint analysis) to substantiate the waste composition designated on the accompanying manifest or other documents. The selection of key parameters must be based on sufficient waste profile knowledge and testing data to ensure accurate representation. When selecting fingerprint parameters, consideration should be given to those that: identify unpermitted wastes; determine suitability within the facility's operational acceptance limits; identify potential reactivity or incompatibility; indicate any changes in composition that had occurred during transportation or storage. Should fingerprint testing results of a given waste stream fall outside the established tolerance limits, the waste may be re-evaluated for possible acceptance to prevent the unnecessary movement of waste back and forth between the generator and the installation. Re-evaluation should consider facility conditions for storage and processing; additional parameter analysis deemed appropriate by the operator and established in the WAP; permit requirements.

25. The inspection scheme may include: assessment of combustion parameters; blending tests on liquid wastes prior to storage; control of flashpoint; and screening of waste input for elemental composition, for example by ICP, XRF and/or other appropriate techniques, in accordance to waste types and characteristics, and the facility waste acceptance criteria. (Karstensen, 2008a)

26. Wastes should be moved to the storage area only after acceptance. Should the inspection or analysis indicate a failure to meet the acceptance criteria, including damaged or unlabelled drums, such loads should be stored in a quarantine area, allocated for non-conforming waste storage, and dealt with appropriately.

27. All areas where hazardous waste is handled should have an impervious surface with a sealed drainage system. Attention should be given to ensuring that incompatible substances do not come into contact resulting from spills from sampling, for example, within a sump serving the sampling point. Absorbents should be available.

28. In accordance with national legislation and practice, suitable provisions should be made to verify that wastes received are not radioactive, such as the use of plastic scintillation detectors.

29. After acceptance, containerised hazardous waste should be labelled with the arrival date and primary hazard class. Where containers are bulked, the earliest arrival date of the bulked wastes should be indicated on the bulk container. Each container should be given a unique reference number for in-plant tracking.

Non-conforming waste

30. The operator should have clear and unambiguous criteria for the rejection of wastes, including wastes that fail to meet the acceptance criteria, and damaged, corroded or unlabelled drums. A written procedure for tracking and reporting such non-conformance should include notification to the customer or waste generator and competent authorities.

31. The operator should also have a clear and unambiguous policy for the subsequent storage, including a maximum storage volume, and disposal of rejected wastes. This policy should achieve the following:

(a) Identify the hazards posed by the rejected wastes;
(b) Label rejected wastes with all information necessary to allow proper storage and segregation arrangements to be put in place;
(c) Segregate and store rejected wastes safely pending removal within no more than five working days, where possible.

32. Wastes not fulfilling the acceptance criteria of the plant should be sent back to the waste generator, unless an agreement is reached with the generator to ship the rejected waste to an alternative authorised destination.

In-plant tracking system

33. An internal wastes tracking system and stock control procedure should be in place, starting at the pre-acceptance stage, to guarantee the traceability of waste processing and enabling the operator to:

(a) Prepare the most appropriate waste blend;
(b) Prevent unwanted or unexpected reactions;
(c) Ensure that the emissions are either prevented or reduced;
(d) Manage wastes throughput.

34. The tracking system, which may be a paper-based, electronic, or a combination of both), should trace the waste during its acceptance, storage, processing and removal off-site. At any time, the operator should be able to identify the location of a specific waste on the facility and the length of time it has been there. Records should be held in an area removed from hazardous activities to ensure their accessibility during any emergency.

35. Once a waste has entered bulk storage or a treatment process, tracking individual wastes will not be feasible. However, records should be maintained to ensure sufficient knowledge is available as to what wastes have entered a particular storage facility. For example, to avoid incompatibility with incoming wastes, it is necessary to keep track of residues building up within a vessel between de-sludging operations.

36. For bulk liquid wastes stock control should involve maintaining a record of the route through the process. Waste in drums should be individually labelled to record the location and duration of storage.

37. The in-plant waste tracking system should hold a complete record generated during pre-acceptance, acceptance, storage, processing and removal off-site. Records should be kept up to date to reflect deliveries, on-site treatment and dispatches. The tracking system should operate as a waste inventory, stock control system and include as a minimum:

(a) A unique reference number;
(b) Details of the waste generator and intermediate holders;
(c) Date of arrival on-site;
(d) Pre-acceptance and acceptance analysis results;
(e) Container type and size;
(f) Nature and quantity of wastes held on-site, including identification of associated hazards;
(g) Details on where the waste is physically located;
(h) Identification of staff who have taken any decisions on acceptance or rejection of wastes.

38. The system adopted should be structured to report on:

(a) Total quantity of waste present on-site at any one time, in appropriate units;
(b) Breakdown of waste quantities being stored pending on-site processing;
(c) Breakdown of waste quantities on-site for storage only, that is, awaiting transfer;
(d) Breakdown of waste quantities by hazard classification;
(e) Indication of where the waste is located relative to a site plan;
(f) Comparison of the quantity on-site against total permitted;
(g) Comparison of time the waste has been on-site against permitted limit.

WASTE STORAGE AND HANDLING

39. After deciding the waste's suitability, the operator should have systems and procedures in place for transfer to appropriate storage safely.

40. Considerations for waste storage on the installation should include:

(a) Location of storage areas;
(b) Storage area infrastructure;
(c) Condition of tanks, drums, vessels and other containers;
(d) Stock control;

(e) Segregated storage;
(f) Site security;
(g) Fire risk.

<u>Design considerations</u>

41. Transfer and storage areas should be designed to handle accidental spills. This may require that:

   (a) To prevent spills from spreading or seeping into the soil, storage areas should have adequate boundaries and be adequately sealed, impermeable and resistant to the stored waste materials;
   (b) All spills should be collected, placed in a suitable container, and stored for disposal in the kiln;
   (c) If a spill occurs, incompatible wastes should be prevented from mixing;
   (d) All connections between tanks should be capable of being closed by valves. Overflow pipes should be directed to a contained drainage system such as a bounded area or another vessel;
   (e) Leak free equipment and fittings should be installed whenever possible;
   (f) Measures to detect leaks and appropriate corrective action should be provided;
   (g) Contaminated runoff should be prevented from entering storm drains and watercourses. Any runoff should be collected and stored for disposal in the kiln;
   (h) Adequate alarms for abnormal conditions should be provided.

42. Storage design should be appropriate to maintain waste quality for the complete storage period. Segregated storage should be in place to prevent incidents from incompatible wastes and as a means of preventing escalation should an incident occur. Individual storage requirements on a particular installation will be dependent on a full assessment of risk.

43. Within the facility, specific storage area characteristics should reflect the properties of the waste that poses the greatest risk that can be accepted. In general, the storage criteria should also take into account the unknown nature and composition of wastes, as this gives rise to additional risks and uncertainties. In many cases, this uncertainty means that higher specification storage systems are applied for wastes than for well-characterised raw materials.

44. Containerised wastes should be stored under cover, protected from heat, direct sunlight and rain, unless the waste is known to be unaffected by such ambient conditions.

45. For containerised wastes, the design should be such to prevent accumulation of hazardous wastes beyond the allowable storage timescale. For liquid wastes, mixing or agitation to prevent settling of solids should be considered. It may be necessary to homogenise tank contents with mechanical or hydraulic agitators. Depending on the waste characteristics, some tanks may need to be heated and insulated.

46. The construction, material selection and design of equipment, such as tanks, pipelines, valves, and seals should be appropriate for the characteristics of the

waste. They should be sufficiently corrosion proof, and offer the option of cleaning and sampling.

47. Adequate ventilation should be provided in consideration to applicable work exposure guidelines. Periodic monitoring should be considered for open stored wastes that may emit VOC.

48. A fire protection system approved by local authorities, for example, a local fire department, should be in place. Automatic fire detection systems should be used in waste storage areas as well as for fabric filters and electrostatic precipitators (ESP), electrical and control rooms, and other identified risk areas. Continuous, automatic temperature measurement of the surface of wastes in the storage pits can be used to trigger an acoustic alarm to indicate temperature variations.

49. Automatic fire suppression systems should be used when storing flammable liquid waste and in other risk areas. Foam and carbon dioxide control systems provide advantages in some circumstances, for example, for the storage of flammable liquids. Water systems with monitors, water cannons with the option to use water or foam, and dry powder systems are commonly used.

Operational considerations

50. Written procedures and instructions for the unloading, handling, and storage of wastes on-site should be in place. It should be ensured that chemically incompatible wastes are segregated. Compliance should be audited regularly.

51. To avoid the need for additional handling and transfer hazardous wastes should be stored in the same containers (drums) that were used for delivery.

52. Designated routes for vehicles carrying specific hazardous wastes should be clearly identified within the facility. On-site transportation should minimize risk to the health and safety of employees, the public and the environment. The operator should ensure that vehicles are fit for purpose with respect to compliance with relevant regulations.

53. All loads should be properly identified, segregated according to compatibility (so that any potential spills do not create chemical safety hazards), and secured to prevent sliding or shifting during transport. Personnel should be directed and trained to use equipment only as intended, and not to exceed the rated capacity of containers, vehicles, and other equipment.

54. Appropriate signage indicating the nature of hazardous wastes should be in place at storage, stockpiling, and tank locations.

55. Containers should be kept in good condition, free of dents, not leaking or bulging, and closed not in use. Container storage areas should have at least a weekly inspection.

56. Maintenance work should be authorized by plant management, and carried out after the area has been checked by a supervisor and all necessary precautions have been taken. Special procedures, instructions, and training should be in place for routine operations such as:

(a) Working at heights, including proper tie-off practices and use of safety harnesses;
(b) Confined space entry where air quality, explosive mixtures, dust, or other hazards may be present;
(c) Electrical lock-out, to prevent accidental reactivation of electrical equipment undergoing maintenance;
(d) ‘Hot works’ (welding, cutting, etc.) in areas that may contain flammable materials.

57. Safety measures that should be considered include:

(a) Placing of uncontrolled combustible materials in storage areas should be avoided;
(b) Where there is a risk that has not been avoided or controlled, standard safety signs and information signs should be in place;
(c) Emergency showers and eye wash stations should be provided within the work area for immediate emergency use following exposure to hazardous wastes. Consideration should be given to the possible need for multiple emergency shower installations, based upon access distance, and the possibility that more than one person may be affected at the same time;
(d) Adequate alarms should be provided to alert all personnel about emergency situations;
(e) On site communication equipment should be maintained so that in case of a fire, the control room and the local fire department can be contacted immediately;
(f) Electrical equipment should be earthed and have appropriate anti-static devices in place.

WASTE PRE-PROCESSING

58. So as not to detract from normal kiln operation, product quality, or the site’s usual environmental performance, wastes used in cement kilns should be homogenous, with compatible particle size, stable chemical composition and heat content. For optimum operation, kilns require very uniform waste material flows in terms of quality and quantity. For certain types of wastes, this can only be achieved by pre-processing.

59. Pre-processing includes drying, shredding, grinding or mixing depending on the type of waste. It is usually carried out in a purpose-made facility, which may be located outside or inside the cement plant.

60. Liquid waste fuels are normally prepared by blending different products with suitable calorific values and chemistry, such as spent solvents or used oil. Only simple pre-treatment is usually necessary, such as the removal of bottoms, sediments and water. In some cases, for example machining oil/emulsion, chemical processes are necessary to remove metallic pollutants and additives. The extent of solid waste processing, such as sorting, crushing, or pelletizing, depends on the specific application.

Design considerations

61. Facility layout should be carefully considered to ensure access for day-to-day operations, emergency escape routes, and maintainability of the plant and equipment.

62. Recognized standards should be applied to the design of installations and equipment. Any modifications should be documented.

63. Health and safety assessments should be undertaken on operations to ensure equipment safety and to minimize risks of endangering people or installations, or damaging the environment. Appropriate procedures should be used to assess risks or hazards for each stage of the design process. Only competent and qualified personnel should undertake or oversee such hazard and operating studies.

Operational considerations

64. Although mixing and homogenisation of wastes can improve feeding and combustion behaviour, it can involve risks and should be carried out according to a prescribed preparation.

65. Techniques used for waste pre-processing and mixing are wide ranging, and may include:

    (a) Mixing and homogenising of liquid wastes to meet input requirements, for example, viscosity, composition and/or heat content;
    (b) Shredding, crushing, and shearing of packaged wastes and bulky combustible wastes;
    (c) Mixing of wastes in a storage pit or similar enclosure using a grab or other machine.

66. Crane operators should be capable of identifying potentially problematic loads, for example, baled wastes and discrete items that cannot be mixed or may cause loading and feeding problems. These can then be removed, shredded or directly blended (as appropriate) with other wastes.

67. General tidiness and cleanliness should be applied to enhance working environment and to allow potential operational problems to be identified in advance. The main elements are:

    (a) Systems to identify, locate and store wastes received according to their risks;
    (b) The prevention of dust emissions from operating equipment;
    (c) Effective wastewater management;
    (d) Effective preventive maintenance.

PRE-PROCESSING PLANT CLOSURE/DECOMMISSIONING

68. Closure is the period directly after the facility stops normal operations. During this period the facility stops accepting hazardous waste; completes storage and processing of any wastes left on site; and disposes or decontaminates equipment, structures, and soils, restoring the site, insofar as possible, to its original condition or in keeping with the intended land use. Planning for decommissioning of the facility should be undertaken during the initial stages of the overall project. By integrating decommissioning requirements into the facility design at the outset, the site development plan should be compatible with the proper closure requirements when the operation of the facility has ended.

69. Operators should be required to properly close the facility in a manner that minimizes the further need for maintenance, and prevents the escape of any hazardous contaminants to the environment. To ensure this, a closure plan should be prepared identifying the steps necessary to partially or completely close the facility, including:

    (a) Procedures for handling removed inventory;
    (b) Procedures for decontamination and/or disposal;
    (c) Procedures to confirm effectiveness of decontamination, demolition and excavation, including procedures for performing sample collection and analysis;
    (d) Health and safety plan addressing all health and safety concerns pertinent to closure activities;
    (e) Security system to prevent unauthorized access to the areas affected by closure activities.

70. To prevent a facility from ceasing operations and failing to provide for the potentially costly closure requirements, operators should be required to demonstrate that they have the financial resources to properly conduct closure in a manner that protects both human health and the environment.

71. To minimise decommissioning problems and associated environmental impacts, it is recommended for existing installations, where potential problems are identified, to put in place a programme of design improvements (EIPPCB, 2006). These design improvements should ensure that underground tanks and piping are avoided. If replacement is not possible operators should provide secondary containment or develop a suitable monitoring programme. A procedure for the draining and cleaning out of vessels and piping prior to dismantlement, among others, should also be provided.

OTHER ENVIRONMENTAL ASPECTS

Volatile organic compounds, odours and dust

72. Emissions to air from waste pre-processing will depend on the types of wastes treated and the processes used. Emission monitoring and reporting should be performed according to operating permits and applicable regulations.

73. Abatement techniques should be in place as required and countermeasures for noise and odours considered. Dust is usually reduced by bag filters while VOC emission control technologies, if needed, may include carbon adsorption, thermal or biological treatments, among others.

74. In the EU, BAT is to apply the following techniques to prevent or control the emissions of dust, odours and VOC in the waste treatment sector as a whole: restrict the use of open topped tanks, vessels and pits; use an enclosed system with extraction to suitable abatement plant; apply a suitably sized extraction system; correctly operate and maintain the abatement equipment; have leak detection and repair procedures in place; and reduce air emissions by using a suitable combination of preventive and/or abatement techniques (EIPPCB, 2006).

Drums and ferrous metals

75. Empty drums and ferrous metals removed by magnetic separators should be disposed of in an environmentally sound manner. Scrap metal not contaminated by chemicals or scheduled wastes can be recycled for steelmaking. Empty waste drums contaminated by chemicals or scheduled wastes in good condition can be sent to authorised/licenced drum washers/recyclers.

Wastewater

76. Discharges of wastewater to surface water should not result in contaminant concentrations in excess of local ambient water quality criteria, or in their absence, other recognized ambient water quality criteria. Receiving water use and assimilative capacity, taking other sources of discharges to the receiving water into consideration, should also influence the acceptable pollution loadings and effluent discharge quality.

77. Discharges into public or private wastewater treatment systems should meet the pre-treatment and monitoring requirements of that sewer treatment system. It should not interfere, directly or indirectly, with the operation and maintenance of the collection and treatment systems, or pose a risk to worker health and safety, or adversely impact characteristics of residuals from wastewater treatment operations.

78. In the EU, BAT is to apply the following techniques to wastewater management in the waste treatment sector as a whole: reduce the water use and the contamination of water; avoid the effluent by-passing the treatment plant systems; collect spillages, drum washings, etc.; segregate the water collecting systems; have a concrete base in all the treatment areas; maximise the reuse of treated wastewaters; conduct daily checks on the effluent management system; carry out the appropriate treatment technique for each type of wastewater; achieve adequate water emission values before discharge by applying a suitable combination of techniques (EIPPCB, 2006).

EMISSIONS MONITORING AND REPORTING

79. Emissions and air quality monitoring programmes provide information that can be used to assess the effectiveness of relevant management strategies. A systematic planning process is recommended to ensure that data collected are adequate for the intended purposes and to avoid collecting data that are unnecessary. A monitoring programme for air quality should consider baseline monitoring to assess background levels of key pollutants both at and in the vicinity of the facility.

80. When wastewater is discharged, a monitoring programme, with adequate resources and management overview, for wastewater and water quality should be developed and implemented to meet set monitoring objectives.

81. The parameters selected for monitoring should be indicative of the pollutants of concern from the process, and should include parameters that are regulated under compliance requirements. Monitoring programmes should apply national or international methods for sample collection and analysis, such as those published by the International Organization for Standardization (ISO), CEN or the United States EPA. Sampling should be carried out or supervised by trained individuals. Those permitted or certified for this role should conduct the analysis. Sampling and analysis QA/QC plans should be applied and documented to ensure that data quality is adequate for the intended data use. Monitoring reports should include QA/QC documentation.

ANNEX 6

GENERAL RECOMMENDATION ON CO-PROCESSING OF HAZARDOUS WASTE

ANNEX 6 – GENERAL RECOMMENDATION ON CO-PROCESSING OF HAZARDOUS WASTE

OPERATIONAL REQUIREMENTS

1. Safe and responsible co-processing requires careful selection of the feed points in the kiln system as well as comprehensive operational control relating to the specific characteristics and volumes of the waste material.

Feed point selection

2. Adequate feed points should be selected according to relevant characteristics of the waste, including physical, chemical, and toxicological (see **Figure 6A**). Different feed points can be used, most commonly waste is introduced via:

   (a) The main burner at the rotary kiln outlet end;
   (b) A feed chute at the transition chamber at the rotary kiln inlet end (for lump fuel);
   (c) Secondary burners to the riser duct;
   (d) Precalciner burners to the precalciner;
   (e) A feed chute to the precalciner (for lump fuel);
   (f) A mid kiln valve in the case of long wet and dry kilns (for lump fuel).

3. Liquid wastes are typically injected into the hot end of the kiln. Solid wastes may be introduced into the calcining zone at some facilities. This is mid-kiln for long kilns, and onto the feed shelf in the high-temperature section for preheater/precalciner kilns.

4. Solid wastes used as alternative raw materials are typically fed into the kiln system via the normal raw meal supply, the same as traditional raw materials. However materials containing components that can be volatilised at low temperatures (for example, solvents) should be fed into the high temperature zones of the kiln system. Wastes containing volatile organic and inorganic components should not be fed via the normal raw meal supply unless controlled test runs in the kiln, or adequate laboratory tests, have demonstrated that undesired stack emissions can be avoided.

5. Combustible toxic compounds found in some hazardous waste, such as halogenated organic substances, need to be completely destroyed through proper temperature and residence time. In preheater/precalciner kilns, hazardous waste should generally be fed through either the main or the secondary burners. Hazardous and other wastes fed through the main burner, where conditions will always be favourable, decompose under oxidising conditions at a flame temperature of >1800°C (see **Figure 6B**). Waste fed to a secondary burner, preheater or precalciner will be exposed to lower temperatures, though expected burning zone temperatures in the precalciner are typically >1000°C (UNEP, 2007). The kiln should be operated in such a way that the gas resulting from the process is raised, after the last injection of combustion air, in a controlled and homogeneous fashion and even under the most unfavourable conditions, to a temperature of 850 °C for two seconds (cf. Directive 2000/76/EC). In the case of hazardous wastes

with a content of more than 1 per cent halogenated organic substances (expressed as chlorine), the temperature should be raised to 1100°C for at least two seconds.

Figure 6A - Typical waste feed points

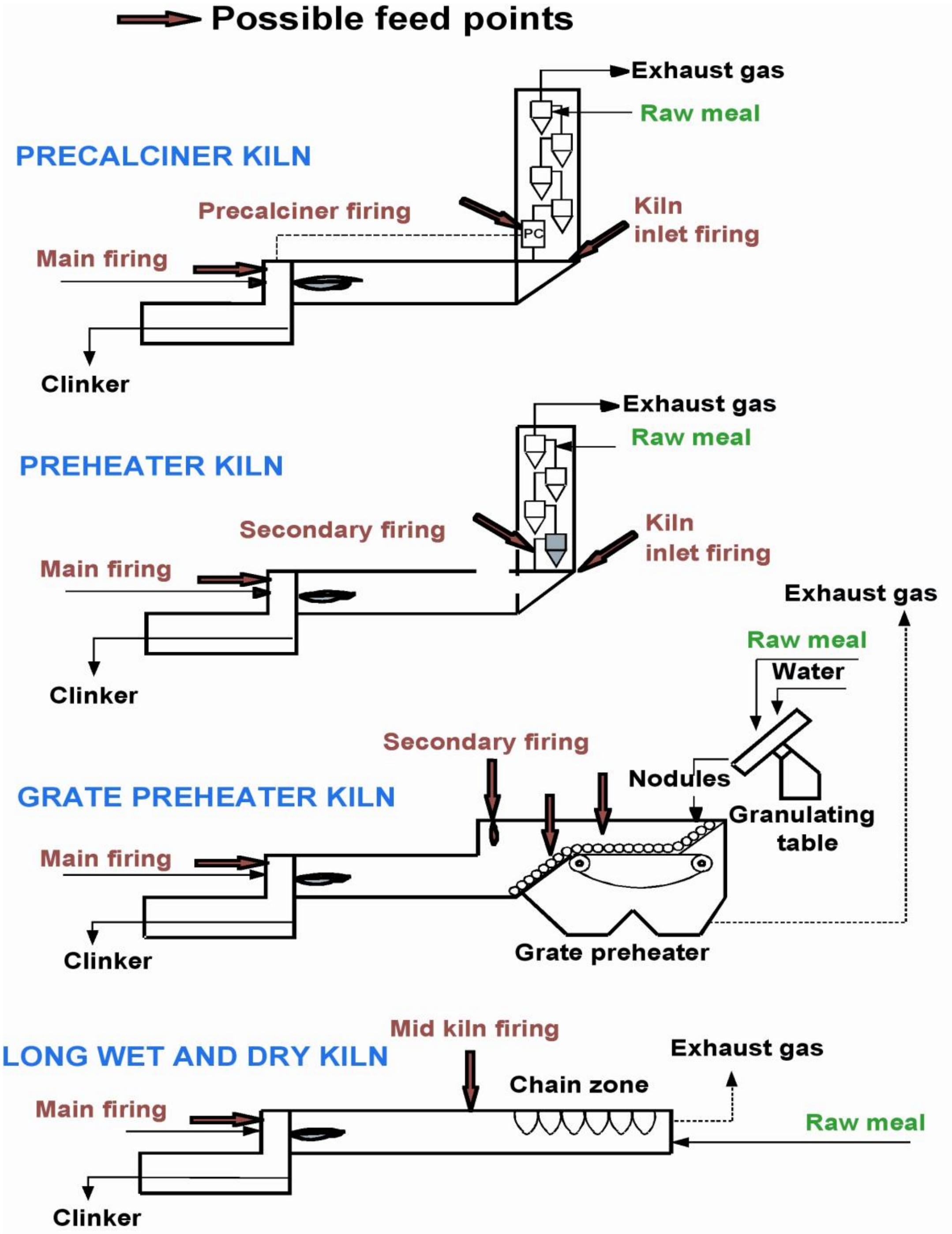
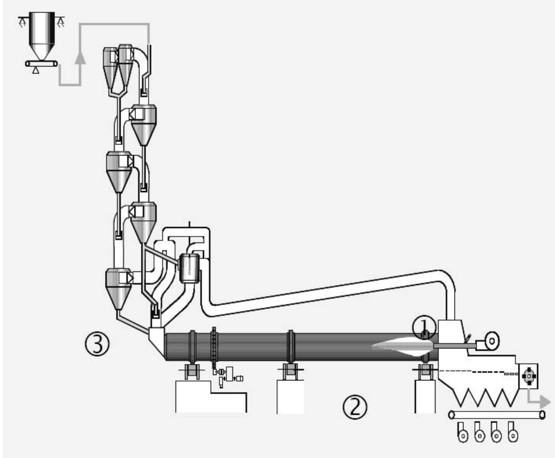


Figure B - Temperatures and residence times during cement manufacture

Characteristics	Temperature and time
Temperature at main burner ① of the rotary kiln ②	>1450°C (material) >1800°C (flame temperature)
Residence time at main burner	>12-15 seconds > 1200°C >5-6 seconds > 1800°C
Temperature at precalciner ③	> 850°C (material) >1000°C (flame temperature)
Residence time at precalciner	> 2-6 seconds > 800°C



6. For hazardous waste feeding into the kiln, the following should be conducted (EIPPCB, 2010):

(a) To use the appropriate feed points to the kiln in terms of temperature and residence time depending on kiln design and kiln operation;
(b) To feed waste materials containing organic components that can be volatilised before the calcining zone into the adequately high temperature zones of the kiln system;
(c) To operate in such a way that the gas resulting from the process is raised, in a controlled and homogeneous fashion and even under the most unfavourable conditions, to a temperature of 850 °C for 2 seconds;
(d) To raise the temperature to 1100 °C, if hazardous waste with a content of more than 1 per cent of halogenated organic substances, expressed as chlorine, is fed into the kiln;
(e) To feed wastes continuously and constantly;
(f) To stop feeding waste when appropriate temperatures and residence times are not maintained or cannot be reached (at start-ups or shutdowns for instance), and whenever any emission limit value is exceeded.

Kiln operation control

7. To avoid operating problems within the kiln, the impact of hazardous waste on the total input of circulating volatile elements, such as chlorine, sulphur or alkalis, requires careful assessment prior to acceptance. Specific acceptance criteria for these components should be set by each facility based on the process type and on the specific kiln conditions.

8. The general principles of good operational control of the kiln system using conventional fuels and raw materials should also be applied to the use of waste. In particular, all relevant process parameters should be measured, recorded, and evaluated continuously. Kiln operators should undergo appropriate training for the requirements related to the use of hazardous waste, including health, safety, and environmental emission aspects.

9. For operational disruptions of the kiln, written work instructions describing the strategy to disconnect the hazardous waste feed to ensure minimum operational stability conditions should be available and known to the kiln operators.

10. The mineral content of the waste may affect the characteristics of the clinker. The raw mix composition should be adjusted accordingly to adhere to the given chemical set points. Input limits for chlorine, sulphur, and alkalis should be defined, and operational set points should be strictly observed. Bypass installations to avoid enrichment cycles of these compounds should only be considered if appropriate solutions for the management of the bypass dust generated have been identified.

11. It is important for combustion and process stability, for the purpose of controlling emissions of unintentionally formed POPs, to ensure (UNEP, 2007):

    (a) Consistency in fuel characteristics (both alternative and fossil);
    (b) Consistency in fuel supply rate or frequency of introduction of batch-charged materials;
    (c) That adequate excess oxygen is supplied to achieve good combustion;
    (d) That concentrations of CO in exhaust gases are monitored and do not exceed pre-established levels reflecting poor combustion conditions.

ENVIRONMENTAL ASPECTS

Air emissions

12. Whether or not wastes are being used in a cement plant, dust (particulate matter),NOx and SO2 emissions cause the greatest concern and needs to be dealt with. Other emissions to be considered are VOC, PCDDs, PCDFs, HCl, CO, CO2, HF, ammonia (NH3), benzene, toluene, ethylbenzene, xylene, polycyclic aromatic hydrocarbons (PAH), heavy metals and their compounds (EIPPCB, 2010). Under some circumstances, emissions may also include chlorobenzenes and PCBs (SBC, 2007).

13. Control technologies should be implemented by the cement plant to ensure compliance to the emission limit as outlined in these guidelines.

Cement kiln and bypass dust

14. All cement plants generate a fine dust from the kiln line, collectively labelled cement kiln dust (CKD). CKD composition varies, even over time from a single kiln line, but includes particulates representing the raw mix at various stages of burning, particles of clinker, and even particles eroded from the refractory brick and/or monolithic linings of the kiln tube and associated apparatus (Van Oss, 2005). Dust is also discarded from alkali bypass systems, installed to avoid excessive build-up of alkali, chloride and/or sulphur, however bypass dust, as opposed to CKD, consists of fully calcined kiln feed material.

15. In the EU, the BAT conclusion for process waste, in the cement manufacturing sector in general, is to re-use collected particulate matter in the process, wherever

practicable, or to utilise these dusts in other commercial products, when possible. (EIPPCB, 2010).

16. To avoid disposal, most CKD and bypass dust is recycled directly back to the cement kiln or cement clinker grinder. In clinker manufacture, CKD partially offsets the need for raw materials such as limestone and natural rock constituents, thus avoiding the energy usage and emissions related to their extraction and processing. Periodically some dust may need to be removed from the system due to increasing concentrations of alkali, chloride and sulphur compounds that may compromise the quality of the clinker. Dust that cannot be recycled back into the process is removed from the system and often collected onsite in piles.

17. Where appropriate CKD not returned to the production process may be recovered in various types of commercial applications, including agricultural soil enhancement, base stabilizing for pavements, wastewater treatment, waste remediation, low-strength backfill and municipal landfill cover (U.S. EPA, 2010). These applications depend primarily on the chemical and physical characteristics of the CKD.

18. The major factors determining CKD characteristics are the raw feed material, type of kiln operation, dust collection systems, and fuel type. Since the properties of CKD can be significantly affected by the design, operation, and materials used in a cement kiln, the chemical and physical characteristics of CKD must be evaluated on an individual plant basis. (U.S. EPA, 2010) Until the degree of variability in the CKD has been established, frequent testing is recommended.

19. Depending upon the level of contaminants of concern (for example, heavy metals, POPs), this waste can in some cases be hazardous waste for which special handling and disposal measures apply (UNEP, 2007). A study by Karstensen (2006b) reports an average concentration of 6.7 ng I-TEQ/kg for PCDDs/PCDFs in CKD and a maximum concentration of 96 ng I-TEQ/kg. The same study shows that wastes from the cement industry have PCDD/PCDF levels in the same magnitude as foods such as fish, butter, breast milk, and less than the maximum permissible concentration of 100 ng TEQ/kg for sewage sludge applied to agricultural land.

20. To ensure the protection of public health and the environment and to prevent groundwater contamination, bypass dust or CKD, discarded from facilities that use hazardous wastes as supplementary fuels or raw materials, should be analyzed for metal and organic leachate quality parameters if they are to be disposed of on land. The analysis should be conducted during controlled test runs in addition to ongoing testing that may be required by local regulatory authorities. Releases of dust to the air should also be controlled.

<u>Emissions to water</u>

21. In general, wastewater discharges are usually limited to surface run-off and cooling water only and cause no substantial contribution to water pollution (EIPPCB, 2010). Nevertheless, in the European Union the use of wet scrubbers is a BAT to reduce the emissions of SOx from the flue-gases of kiln firing and/or preheating/precalcining processes (EIPPCB, 2010). As such, the generation and management of wastewater shall subject to the requirements under Environmental

Quality (Effluent) Regulations 2009, so as to limit the transfer of pollutants from the air into water.

End-product control

22. Final products such as clinker and cement are subject to regular control procedures required by the usual quality specifications as laid down in applicable national or international quality standards.

23. As a principle, co-processing should not alter the quality of the cement being produced. This means that the clinker, cement or concrete produced should not be used as a sink for heavy metals. There should be no negative impact on the environment as might be demonstrated with leaching tests on concrete or mortar, for example. The quality of cement should also allow end-of-life recovery.

24. Organic pollutants in the materials fed to the high temperature zone of the kiln system are completely destroyed, while the inorganic components are incorporated into the end product. Accordingly, the use of wastes in the clinker burning process may change the metal concentrations in cement products, and depending on the total input via the raw materials and fuels, the concentration of individual elements in the product may increase or decrease as a result of waste co-processing (EIPPCB, 2010). However, lengthy investigations have shown that the effect of waste on the heavy metals content of clinker is marginal on a statistical basis, the one exception being the bulk use of tires which will raise zinc levels (GTZ, 2006).

25. As cement is blended with aggregates to form concrete or mortar, it is the behaviour of the metals within these building materials that is important for the evaluation of relevant environmental impacts of waste used in the production process. Studies have shown that metal emissions from concrete and mortar are low, and comprehensive tests have confirmed that metals are firmly incorporated in the cement brick matrix. In addition, dry-packed concrete offers high diffusion resistance, which further counteracts the release of metals. Tests on concrete and mortar have shown that the metal concentrations in the eluates are noticeably below those prescribed, for instance, by national legislation. Moreover, storage under different and partly extreme conditions has not led to any environmentally relevant releases, which also holds true when the sample material is crushed prior to the leaching tests. (EIPPCB, 2010).

26. In regard to the above, the main results of leaching studies done to assess the environmental impacts of heavy metals embedded in concrete are as follows (GTZ, 2006):

   (a) The leached amounts of all trace elements from monolithic concrete (service life and recycling) are below or close to the detection limits of the most sensitive analytical methods;

   (b) No significant differences in leaching behaviour of trace elements have been observed between different types of cements produced with or without alternative fuels and raw materials;

(c) The leaching behaviour of concrete made with different cement types is similar;

(d) Leached concentrations of some elements such as chromium, aluminium and barium may, under certain test conditions, come close to limits given in drinking water standards; hexavalent chromium in cement is water-soluble and may be leached from concrete at a level higher than other metals, so chromium inputs to cement and concrete should be as limited as possible;

(e) Laboratory tests and field studies have demonstrated that applicable limit values, for example, groundwater or drinking water specifications, are not exceeded as long as the concrete structure remains intact. For example, in primary or service life applications;

(f) Certain metals such as arsenic, chromium, vanadium, antimony, or molybdenum may have a more mobile leaching behaviour, especially when the mortar or concrete structure is crushed or comminuted (for example, in recycling stages such as use as aggregates in road foundations, or in end-of-life scenarios such as landfilling);

(g) As there are no simple and consistent relations between the leached amounts of trace elements and their total concentrations in concrete or in cement, the trace element content of cements cannot be used as environmental criteria.

27. Assessments of the environmental quality of cement and concrete are typically based on the leaching characteristics of heavy metals to water and soil. Various exposure scenarios need to be considered (GTZ, 2006):

(a) Exposure of concrete structures in direct contact with groundwater ('primary' applications);

(b) Exposure of mortar or concrete to drinking water in distribution (concrete pipes) or storage systems (concrete tanks) ('service life' applications);

(c) Reuse of demolished and recycled concrete debris in new aggregates, road constructions, dam fillings etc. ('secondary' or 'recycling' applications);

(d) Dumping of demolished concrete debris in landfills ('end-of-life' applications).

28. Careful selection and monitoring of the waste ensure that the use of wastes does not result in metal emissions of any environmentally harmful magnitude (EIPPCB, 2010). However, in cases where the concentration of heavy metals exceeds the normal range found in cements made without alternative fuels and/or materials, leaching tests on mortar and/or concrete should be conducted (GTZ, 2006).

29. For "real-life" concrete and mortar exposure scenarios, different leaching tests and assessment procedures should be applied. Although standardized test procedures exist for waste management regulations and drinking water standards, there remains a need for harmonized and standardized compliance test procedures based on the exposure scenarios outlined above. It is recommended that a certified independent testing laboratory perform these at least annually.

MONITORING

30. Emission monitoring should be conducted to allow authorities to check compliance with the conditions in operating permits and regulations, and to help operators manage and control the process, thus preventing emissions from being released into the atmosphere. It is the responsibility of the competent authority to establish and set appropriate quality requirements, and to consider a range of safeguards. For the purpose of compliance assessment use of the following is considered good practice (EIPPCB, 2003):

    (a) Standard methods of measurement;
    (b) Certified instruments;
    (c) Certification of personnel;
    (d) Accredited laboratories.

31. For self-monitoring activities the use of recognised quality management systems and periodic check by an external accredited laboratory instead of formal own accreditation can be appropriate (EIPPCB, 2003).

32. More useful information regarding monitoring principles can be found in the European Commission's Reference Document on the General Principles of Monitoring (EIPPCB, 2003).

Process monitoring

33. To control kiln processes, continuous measurements are recommended for the following parameters (UNEP, 2007; EIPPCB, 2010):

    (a) Pressure;
    (b) Temperature;
    (c) O2;
    (d) NOx;
    (e) CO;
    (f) SO_2 , when the SOx concentration is high (it is a developing technique to optimise CO with NOx and SO_2).

34. In the EU, the BAT conclusion for the cement manufacturing sector as a whole is to carry out monitoring and measurements of process parameters and emissions on a regular basis, such as (EIPPCB, 2010):

    (a) Continuous measurements of process parameters demonstrating process stability, such as temperature, O2, pressure, exhaust gas flow rate, and of NH3 emissions when using selective non-catalytic reduction (SNCR);
    (b) Monitoring and stabilising critical process parameters, for example, homogenous raw material mix and fuel feed, regular dosage and excess O_2.

Emissions monitoring

35. To accurately quantify the emissions, continuous measurements is BAT for the following parameters (UNEP, 2007):

(a) Exhaust gas flow rate;
(b) Moisture (humidity);
(c) Temperature;
(d) Dust (particulate matter);
(e) O2;
(f) NOx;
(g) SO_2;
(h) CO.

36. Continuous measurement of TOC is also recommended. The operator should assure proper calibration, maintenance, and operation of the continuous emission monitoring systems (CEMS). A quality assurance programme should be established to evaluate and monitor CEMS performance on a continual basis.

37. Periodical monitoring at a minimum once per year is appropriate for the following substances:

(a) Metals (Hg, Cd, Tl, As, Sb, Pb, Cr, Co, Cu, Mn, Ni, V) and their compounds;
(b) HCl;
(c) HF;
(d) NH3;
(e) PCDDs/PCDFs.

38. The BAT according to EIPPCB (2010) is to carry out monitoring and measurements of process parameters and emissions on a regular basis, such as:

(a) Continuous measurements of dust, NOx, SOx and CO emissions;
(b) Periodic measurements of PCDDs/PCDFs and metals emissions;
(c) Continuous or periodic measurements of HCl, HF and TOC emissions.

39. It is also possible to measure and monitor NH_3 and Hg continuously, and to sample PCCDs/PCDFs and PCBs continuously for analysis from 1 to 30 days (EIPPCB, 2010).

40. Performance tests should be conducted to demonstrate compliance with the emission limits and performance specifications for continuous monitoring systems, when the kiln is operating under normal conditions.

41. Measurements of the following may be required under special operating conditions (UNEP, 2007; EIPPCB, 2010):

(a) Benzene, toluene and xylene (BTX);
(b) Polycyclic aromatic hydrocarbons (PAHs);
(c) Other organic pollutants (for example, chlorobenzenes, PCBs including coplanar congeners, chloronaphthalenes, etc).

42. In case of hazardous waste disposal in cement kilns for the purpose of destruction and irreversible transformation of the POPs content in waste, the DRE should be determined (UNEP, 2007) and it is referred to the Updated General Technical Guidelines for the Environmentally Sound Management of Wastes Consisting of,

Containing or Contaminated with Persistent Organic Pollutants (POPs) (SBC, 2007).

Environmental monitoring

43. Justifiable concerns about the environmental impact from the plant may require the implementation of an ambient air-monitoring programme. This should assess levels of key pollutants identified as a priority for environmental control. The arrangements should include control and downwind locations, including the area of maximum ground level deposition from stack emissions. A meteorological station should be provided for the duration of the ambient sampling exercise in a location free from significant interference from buildings or other structures.

Reporting requirements

44. Reporting of monitoring results involves summarising and presenting results, related information and compliance findings in an effective way. Good practice is based on consideration of: the requirements and audiences for reports, responsibilities for producing reports, the categories of reports, scope of reports, good reporting practices, legal aspects of reporting and quality considerations (EIPPCB, 2003)

45. Monitoring reports can be classified as follows (EIPPCB, 2003):

(a) Local or basic reports, which are usually prepared by operators (for example, as part of their self-monitoring) and, where appropriate, should meet any permit requirements. These reports may concern, for example, an individual installation, an occurrence, which covers a short period and needs to be reported promptly, or local audiences;

(b) National or strategic reports, which will generally be prepared by the competent authorities. These are usually summary reports and they typically concern, for example, several installations, longer periods in order to show trends, or national audiences;

(c) Specialised reports, which are reports on relatively complex or novel techniques that are occasionally used to supplement more routine monitoring methods (for example, telemetry, neural networks, or deposition surveys).

46. Good practices in the reporting of monitoring information include (EIPPCB, 2003):

(a) Data collection, which involves the acquisition of basic measurements and facts. Considerations of the following items are good practice in data collection: schedules (stating how, when, by whom and to whom the data are to be reported, and what types of data are acceptable); use of standard forms for collecting data; data qualification details (used to record whether data values are based on measurements, calculations or estimations); uncertainties and limitations data (details of detection limits, numbers of samples available); operational context details (details of the prevailing process operations and/or environmental conditions).

(b) Data management, involving the organisation of data and its conversion into information. Considerations of the following items are good practice in data management: transfers and databases; data processing; software and statistics; and archiving.

(c) Presentation of results, which involves the delivery of information to users in a clear and usable form. Considerations of the following items are good practice in the presentation of monitoring results, depending on the type of report: scope of the report (type of situation, timing requirements, location); programme of presentations; trends and comparisons; statistical significance (details on exceedences or changes that are significant when compared with the uncertainties in measurements and process parameters); interim performance (interim reports); strategic results (details on levels of compliance for different policies, activities, technologies, etc.); non-technical summaries (for the public); and distribution of reports.

47. In order for monitoring reports to be used in decision making processes they should be readily available and accurate (to within stated uncertainties). Good practice in accessibility and quality of the reports can be achieved by considering the following items: quality objectives and checks; competence; contingency arrangements; sign-off systems; retention of data; and falsification of data. (EIPPCB, 2003).

REFERENCES

1. Technical Guidelines On The Environmentally Sound Co-processing Of Hazardous Wastes In Cement Kilns, UNEP, 11 November 2011.

2. Environmental Quality Act 1974 and all related Regulations, Orders and Rules under the Act.

3. Malaysia Standard document MS EN 197-1.

DRAFTING COMMITEE

GUIDELINES ON ENVIRONMENTALLY SOUND CO-PROCESSING AND USE OF SCHEDULED WASTES IN CEMENT KILNS IN MALAYSIA

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