Université de Pau et des Pays de l'Adour
UFR Sciences Techniques de la Côte Basque

LICENCE BIOLOGIE DES ORGANISMES

Analysis of the environmental legislation in Brazil, Argentina, India, Malaysia, Russia, China and South Africa and the implications for Shields Environmental

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Researching a fully sustainable solution for heat sinks containing beryllium oxide

Lara Young

Internship from the 5th March to 25th May 2012
Under the supervision and responsibility of Mr Daniel Jones, Finance Director

Shields Environmental Plc
Kerry Avenue, Purfleet Industrial Park, South Ockendon, Essex,
RM15 4YE, ENGLAND
Telephone: 01708 684000 | fax: 01708 684021| http://www.shields-e.com

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"Le présent rapport constitue un exercice pédagogique qui ne peut en aucun cas engager la responsabilité de l'Entreprise ou du Laboratoire d'accueil"

Acknowledgements

It would not have be possible to write this report without the help and support of the kind members of staff at Shields Environmental, to only some of whom it is possible to give particular mention here.

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Contents

1 Introduction:

Shields Environmental is a now privately owned company originally founded by Gordon Shields in 1979.

Focusing on the telecommunications sector Gordon Shields linked good environmental management practices to revenue return, becoming one of the first companies to provide a sound business case for environmental excellence. The company is headquartered in the UK (Figure 1) and also has offices and facilities in the United States of America, France, Czech Republic and The Netherlands.

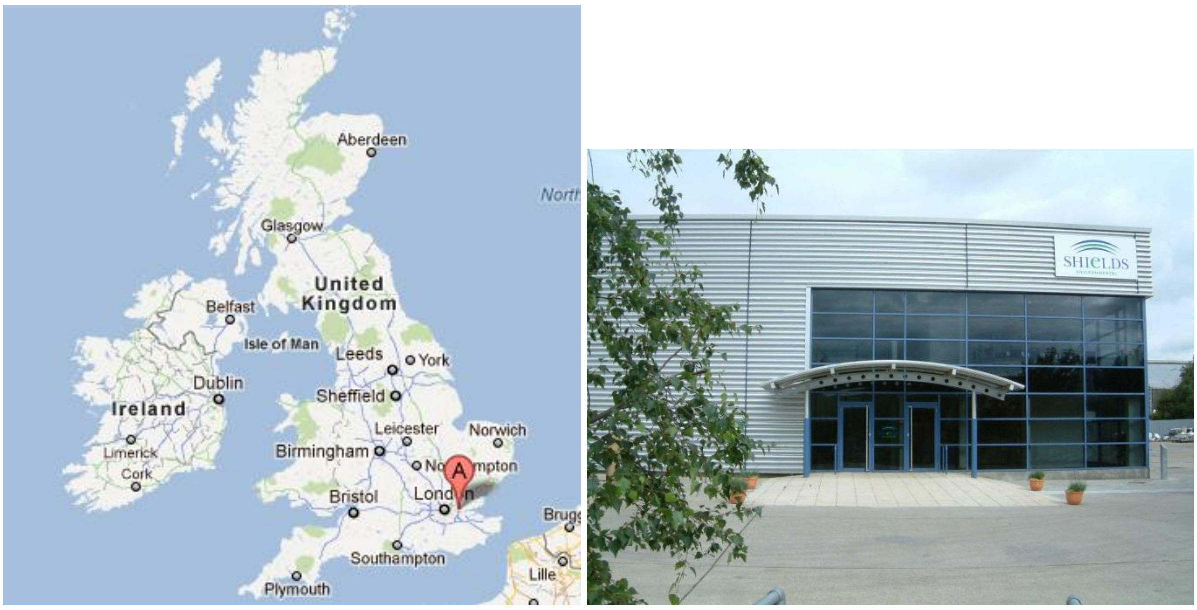

Figure 1: Shields Environmental Headquarters (Sources: Shields Environmental's internal sources and Google Maps)

For nearly thirty years Shields Environmental have been a world leader in optimising network assets for telecoms operators across the globe. They are also a leader in dealing with such assets in the most environmentally sound manner possible. Shields Environmental helps turn cost centres into revenue streams and, as a result, have enabled their clients to manage their networks with maximum financial efficiency and care for the environment. Companies interested in selling their network equipment, are offered a fully managed solution. Including project management, inventory evaluation, de-installation, logistics, repair, refurbishment and testing. Whilst also providing safe and responsible materials recycling, in addition to a complete financial and environmental reporting in full compliance with the waste electrical and electronic equipment (WEEE) directive.

As part of Shields Environmental's continued mission to increase efficiency while reducing environmental impact and cost for their customers, they recently launched an Energy Conservation Service and have become a verified supplier to the Green500.

Green500 is a carbon mentoring scheme initiated by the Mayor of London, aimed at large London organisations across private and public sectors.

Shields Environmental is founded on a unique mission that closely links the interests of business with a passion for the environment.

Furthering their global expansion, it is vital for Shields Environmental to fully comprehend and be aware of all the environmental legislation of specific countries they intend to invest in. Thus during my internship I was entrusted with various projects including compiling a country specific report on the understanding of the environmental legislation implemented within such countries of interest. The target countries I was entrusted to research are listed as follows in order of priority: Brazil, Argentina, India, Malaysia, Russia, China and South Africa.

The aim of this project was to fully understand the current legislation at hand and to ensure full compliance with national and local legislation of each specific country. This research will enable the company to be fully aware and apprehend any specific regulations they must abide by, enabling Shields Environmental to envisage any future problems that they may face if and when they were to invest in such a country. This research would also enable them to abide by their own environmental policies whilst fully complying with the legislation of each country, thus maintaining to act in the most environmentally sound manner possible.

Additionally, over the last decade, Shields Environmental has accumulated a substantial amount of heat sinks containing hazardous powdered beryllium oxide. The heat sinks in question have been extracted over the years from various models of old telecommunications equipment. In compliance with their zero landfill policy and their mission to act in the most environmentally sound manner possible, the hazardous heat sinks have never been disposed of. In effect Shields Environmental's knowledge, no recycling or re-use procedures able to deal with beryllium oxide has been implemented within the United Kingdom or elsewhere. Thus during my three month work placement, Shields Environmental also entrusted me with the project of finding a fully sustainable solution for the hazardous heat sinks currently being stored. The aim of the task at hand was to balance out the needs of the business, in achieving a high financial return on the solution and the environment in maximising re-use and recycling solutions.

The resolution of such an issue would once again provide proof of their long term mission to closely link their interests of business with their passion for the environment. Indeed even after more than ten years of storage, Shields Environmental is still searching for a sustainable solution.

The first part of this report concerns the necessary research on the subject of environmental legislation within Brazil, Argentina, India, Malaysia, Russia, China and South Africa. Within this section, the first part will define what is to be more specifically researched; the choice of organizations and companies contacted is also explained as is the method in which each country-specific report was compiled. The eventual problems faced and main results are also put forward. A third part will act as a conclusion to the research that has been undertaken and what that implies for Shields Environmental. The second half of this report is dedicated to the beryllium oxide project. Within this section, the first part concerns the necessary research required before unfolding the core issue of finding a fully sustainable solution for the hazardous heats sinks currently stored in the second part. This second part explains the various paths followed as to the recycling solutions possible and the different organisations and companies contacted along with their responses. The last portion of this section summarizes the results of the previous parts and acts as a conclusion to the possible sustainable solutions.

Throughout the whole period of the work placement I was permitted to proceed entirely as I felt necessary and worked alone on all projects. All initiatives taken were my own as was the manner in which I proceeded in managing the projects.

2 Analysis of environmental legislation:

2.1 The domains to be researched:

Being headquartered in the UK, Shields Environmental is already obliged to comply with the UK Directive of Waste Electrical and Electronic Equipment (WEEE Directive) of 2007. This directive aims to reduce the amount of electrical and electronic equipment being produced and encourages reuse, recycling and recovery. It also aims to improve the environmental performance of businesses that manufacture, supply, use, recycle and recover electrical and electronic equipment (EEE). In addition to these regulations, Shields Environmental is also obliged to abide by the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal which is an international treaty that was designed to reduce the movements of hazardous waste between nations.

When investing in foreign countries Shields Environmental deals within two major domains. The first is the import and export of EEE, thus a first part of the research required concerned the transport regulations of commodities and more specifically EEE. The second domain is the import, export and recycling of WEEE. Furthermore a certain amount of WEEE contains hazardous components, as listed in the Basel Convention under the “amber list”, and is therefore considered as hazardous waste. Elements not considered hazardous are listed in the “green list” of the Basel Convention. Thus the second part the research concerned the transport regulations of WEEE and hazardous waste in addition to the recycling regulations of such wastes.

In order to understand each countries regulations, within the introduction of each report was a short résumé of the countries legal system and national approach to recycling and more specifically to WEEE.

2.2 Material and method:

In order to deal with each country by its level of priority, I proceeded to conduct my research and construct reports country by country as in not to forget or confuse any elements.

Before contacting any organization or company, I further researched specifically each country as to if they had signed and/or ratified the Basel Convention, how their legal system was set up and functioned, the countries environmental initiatives, and the amount of environmental legislation currently implemented. A general idea as to the national opinion and approach towards recycling and its implementation within the country was also able to be made and included within the introduction of each report.

In order to provide Shields Environmental with the correct and most recent legal details, I only contacted official, legal and government organizations and institutions for each specific country. I also took advantage of Shields Environmental's vast amount of transport company contacts, such as DHL and many other logistics companies, based in numerous different countries in order to obtain any further information and local knowledge they could provide.

I firstly contacted for both EEE and WEEE enquiries national government departments such as the Department of Environmental Affairs, the Department of Foreign Trade and Commerce, the Customs Department and Customs Office by email and telephone. The different countries UK-based embassy offices in London were also contacted in regards to both EEE and WEEE enquiries.

Whilst awaiting responses I analysed the most recent customs regulations, solid waste and hazardous waste regulations, and any other national or local regulations or legal policies found on the various government websites.

Furthering the research, international and national environmental associations and environmental agencies were contacted as to provide any supplementary information. Transport companies and agencies were also contacted in order investigate the complexity and specific forms required for the import and export of EEE and WEEE. The recycling issue was addressed by contacting the main WEEE and/or hazardous waste recyclers in each country independently.

2.3 Results and discussion:

The results for each country were gathered in a detailed report divided into two distinct sections, the first being commodities and the second WEEE. Both sections were subdivided into portions concerning import, export and transit regulations, the classification of such products and the various forms and certificates necessary for such movements. The WEEE section of the reports also contained a portion specifically concerning recycling regulations and the paperwork necessary for such activities. Any local legislation specific to certain regions or states was also included when necessary, as were any case studies that could provide help when dealing within these countries.

In addition to a country-specific report, I constructed a résumé document in the format of a spread sheet divided into four main sections per country. The first regroups the restrictions and quotas applicable to transporting of EEE and WEEE. Also included was the permits, licences and certificates required for such movements and from which government body they should be obtained from. The second section concerns the WEEE regulations or equivalent applied within each country. The third section summarizes local legislation for Argentina, Brazil and China. The last section regroups any important facts that should be known. Each report contains the references and legal documents stated in the report as proof of such regulations if ever Shields Environmental's actions were questioned when dealing in such countries.

Each report may be found in the Annex document supplied with this report as is the résumé spread sheet (Annexes 1 to 8).

China was the country that provided the most detailed, comprehensive and accessible legislation. Argentine legislation was also fairly accessible, however proved itself to be considerably less comprehensive. This was due to the amount of legislation endeavouring to be implemented within the country in order to comply with international standards and treaties, to an extent that numerous laws and policies are hugely contradictory. Therefor obtaining a clear definition as to the correct protocol to apply is greatly challenging. A similar situation is obvious within Brazil and India, however national legislation is far more arduous to obtain and government departments are far less willing to comply and provide any information as of such. Malaysian and South African legislation was laborious to obtain yet exceedingly less contradictory, however greatly lacking any specific legislation concerning WEEE whether it concerned recycling procedures or transport regulations. Nevertheless, the most difficult legislation to research was by far Russian environmental legislation. Asides the government websites requesting to refrain from submitting any questions if not in Russian, no legal documents are available nor were any government bodies predisposed to supply any help or information when telephoned. Thus the report concerning Russia lacks information and is poorly detailed in comparison to the other reports.

2.4 Conclusion:

With the results provided Shields Environmental was able to acquire a general idea as to what they are to deal with when working and investing in such countries. The information provided was sufficient for all target countries besides Russia. Additional information and confirmation of certain aspects was required for Brazil, India and Malaysia and was dealt with in the same manner as the research before was conducted.

The country reports along with the résumé spread sheet and additional information provided sufficient for Shields Environmental.

3 Researching a fully sustainable solution for heat sinks containing beryllium oxide:

In order to address the issue at hand concerning the heat sinks currently stored at Shields Environmental (Figure 2), various steps were to be taken methodically.

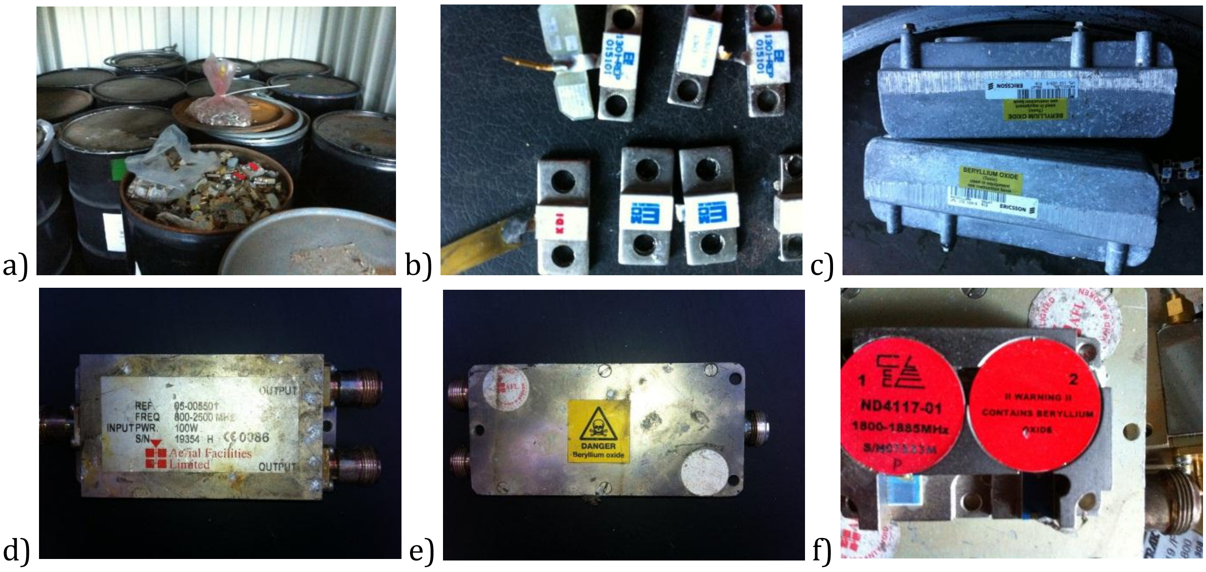

Figure 2: Various heat sinks currently stored at Shields Environmental:
a: Metal drums containing the different heat sinks
b: KDI and EMC heat sinks
c: Ericsson heat sinks
d and e: An Aerial Facilities Ltd heat sink
f: An LCC or CCC heat sinks
(Source: personal photographs)

Firstly, a general idea of the different elements being dealt with was required in order to fully comprehend the product. Secondly, confirmation from the manufacturers concerning the composition of the numerous varieties of heat sinks was essential in order to correctly orientate my future research into this issue. Thirdly, the knowledge of current recycling procedures of beryllium oxide was required, and subsequently their possible use as a solution for this specific case.

3.1 Materials and methods:

3.1.1 The research beforehand:

The first element of research I conducted was to comprehend the functions and uses of heat sinks in addition to understanding beryllium as an element and more specifically how beryllium oxide is obtained from beryllium. I then furthered my research on the understanding of beryllium oxide, discovering its domains of application, applicable processes, health hazards and potential outlets.

Furthering my research into the subject of heat sinks I discovered their general functions and uses within electrical and telecommunications equipment. Following this, a brief summary was written on the subject of beryllium allowing to obtain an overall idea of the initial element at hand that Shields Environmental and I are to deal. The summary includes a basic description and the main characteristics of the elements, its common uses, its industrial and commercial uses. Especially within the telecommunications industry, the classification and disposal of such an element and the health hazards it represents in regards to the different forms it can be found under. The different occurring illnesses due to exposure, the possible means of contamination and the consequences of such exposure are also summarized.

During this process, the matter of beryllium oxide was investigated. A similar résumé to the one concerning beryllium was written. Including a section on the means in which the oxide is obtained and the specific implication of its utilization within electrical and telecommunications equipment. Notably issues that occur during the management of the disposal and recycling of such products and the health hazards threats and risks that have to be taken into consideration for such activities.

The research ended on the subject of current or possible procedures for recycling beryllium oxide and other beryllium compounds. The investigation into such procedures was lead at first, on a national level of the United Kingdom (UK). This did not result in any positive answers as there are no procedures currently in place. Therefore the search was broadened to a European level which still provided only a few feasible applications. Thus the scale was widened to an international and global level, from which a general picture as to the present recycling situation of beryllium oxide was able to be drawn.

A case study was found specifically based on the recycling potentials of beryllium oxide in WEEE. It was analysed for new and further information, however it is still at present solely a research paper and not of yet an implemented method of recycling.

3.1.2 <u>Identifying the composition of the heat sinks stored at Shields Environmental:</u>

Following the research into the various elements these heat sinks are supposedly composed of, the next step was to confirm the composition of them. This would enable for the correct information to be given to the recycler as to what components and elements they would have to deal with and recycle.

As a means to identify the different materials used in the heat sinks, the first initiative taken was to record the names printed on the products and any other references visible such as serial, part or model numbers. A list was then created with the names recorded and their correspondent references. An important amount of heat sinks did not possess any names or brands on them; the list created is therefore non-exhaustive.

Nevertheless, from the list produced, most of the corresponding original equipment manufacturers (OEMs) were able to be identified and subsequently the technical and production departments were contacted in regards to the particular heat sinks they produced. I was unable to provide the manufacturers with an estimated date of production as the telecommunication equipment the heat sinks were extracted from had been received at different periods over the last decade; moreover the age of the different pieces of equipment is unknown to Shields Environmental.

3.1.3 Reuse and recycling possibilities:

Once the identification of the materials and components of only certain heat sinks was accomplished, as not all could be identified, various varieties of companies were approached in regards to the subject of recycling them. Whether it be through a take-back scheme, by reusing the heat sinks in their current state, recycling them as a whole product or by dismantling them into separate parts and safely disposing of them in an environmentally sound manner.

The most environmental sustainable solution being the reuse of the product in its current state, the first variety of companies to be contacted were once again the OEMs. Although the department approached were the corporate responsibility (CR) departments in view of distinguishing whether they were willing and interested in a take-back scheme, if not already existing within their company.

Secondly, in relation to a similar enquiry for the creation of a take-back scheme if not already existent, the corporate departments of the major electronics manufacturing services (EMSs) were approached. In effect these companies test, manufacture, distribute and provide return and repair services for electronic components and assemblies for OEMs. It is for these reasons such companies were contacted as in obligation to comply with environmental legislation they are required to provide sustainable solutions for their products and thus may possess a solution for the heat sinks at Shields Environmental. The companies were contacted firstly as to whether the products they previously used contained beryllium oxide, as beryllium oxide has now been phased out of most telecommunications equipment. Secondly, they were asked if they were able to re-use or recycle such products, if so by what manner or if they knew of any processes that could be applied. The companies dealt with are multinational hence various CR departments were contacted with the aim of optimizing the investigation, widen the search and avoid being overlooked due to lack of communication between such large entities.

Furthering the enquiry, the few producers of beryllium oxide and other beryllium compounds were approached enquiring as to whether they disposed of or knew of any recycling solutions applicable to the products in question. The companies approached ranged from multinational companies based worldwide to UK based companies and local producers.

Continuing the research into a sustainable solution, companies that use or could possibly use beryllium oxide or beryllium compounds were contacted. The companies contacted are specialised in a variety of domains. Many were smelters and sinters who could possibly melt the heat sinks as a whole in order to obtain a finished metal product that had acquired the characteristics that beryllium oxide provides. Others were metal producers that produced beryllium alloys or other such products that require beryllium compounds, numerous other companies having an interest in beryllium oxide were contacted. The search was based largely on a European scale in particular within the UK, in aim to keep transport cost as low as possible.

After searching companies that had a need for beryllium oxide, recyclers specialized in WEEE and/or hazardous wastes were approached. This particular research was also mainly based on European recyclers, especially UK based organisations.

3.2 Results and discussion:

3.2.1 Results and discussions on the research beforehand:

As a proof of Shields Envrionmental's perpetual motivation to provide the most environmentally sound solution possible, I was asked to construct a report of my findings with the corresponding companies approached and their responses. The document is to be presented to Vodafone, the largest network company in Europe and has been one of Shields Environmental's clients for over ten years, as proof of their continual search. This report may be found in Annex 14 provided with this report.

The results of the research conducted beforehand provided valuable information on the elements to be dealt with in addition to providing a better understanding of the current recycling situation on a UK, European and global scale.

The résumé of each subject in more detail may be found in Annex 14 provided with this report. Firstly the subject of heat sinks, within electronic systems. A heat sink is a passive component that cools a device by dissipating heat into the surrounding air. They are designed to increase the surface area in contact with the cooling medium surrounding it, such as air. Heat sinks are necessary devices that enable to cool various electrical devices such as computer central processing units or graphics processors (Kordyban, 1998).

Secondly beryllium (Be), as a free element beryllium is a steel-grey, strong, lightweight and brittle alkaline earth metal. It is primarily used as a hardening agent in alloys, notably beryllium copper as beryllium metal has a resistance to deformation almost 50% greater than that of steel with only about one-fourth the weight. A high flexural rigidity, thermal stability and a thermal conductivity of 216 watts per meter kelvin ensure beryllium to be the metal with the best heat dissipation characteristics per unit weight. The high thermal conductivities of beryllium and beryllium oxide have led to their use in heat transport and heat sinking applications. (Jakubke, Hans-Dieter and Jeschkeit, Hans, 1994).

The commercial use of beryllium metal presents technical challenges due to its toxicity, particularly through inhalation of beryllium-containing dusts. Beryllium is corrosive to biological tissue; frequent exposure is often the cause of a chronic life-threatening allergic disease named chronic beryllium disease (CBD) or berylliosis. The lung is the main target organ of beryllium toxicity in humans. Beryllium lung disease can persist up to a year and can be fatal. The International Agency for Research on Cancer (IARC) has recently listed beryllium and beryllium compounds as Category 1 carcinogens that is to say an agent considered carcinogenic to humans (Puchta Ralph 2011).

Currently beryllium metal component waste is classified as non-hazardous by the Organisation for Economic Co-operation and Development (OECD), the Basel Convention and the EU Waste Control Systems. However, it is recommended that beryllium metal components should be segregated from equipment at end-of-life and returned to the supplier for recycling (Environmental Protection Agency, 1994).

Thirdly, beryllium oxide (BeO), also known as beryllia, is a colorless solid and a notable electrical insulator with a higher thermal conductivity than any other non-metal except diamond, and in truth exceeds that of some metals (Greenwood N.N and Earnshaw A, 1997).

As an amorphous solid or non-crystalline solid, beryllium oxide is white. Its high melting point of 1278°C leads to its use as a refractory, that is to say a material that retains its strength at high temperatures. Beryllium oxide occurs on earth as the mineral named bromellite, a rare mineral to encounter in its natural state; however Bromellite has been synthetically produced for over 40 years.

Beryllium oxide is prepared by three main processes:

- Calcining beryllium carbonate: $BeCO_3 \rightarrow BeO + CO_2$
- Dehydrating beryllium hydroxide: $Be(OH)_2 \rightarrow BeO + H_2O$
- Igniting beryllium: $2Be + O_2 \rightarrow 2BeO$

Unlike other oxides, beryllium oxide is amphoteric rather than basic, therefore constituting a molecule that is able to react as an acid as well as a base (Greenwood N.N and Earnshaw A, 1997).

Sintered beryllium oxide, a method used to create objects from powders, is extremely stable and possess ceramic characteristics. Beryllium oxide is also utilised in many high-performance semiconductor parts for applications such as radio equipment due to its high thermal conductivity whilst also being an excellent electrical insulator. It is used as a filler in certain thermal interface materials such as thermal grease. Certain power semiconductor devices such as heat sinks have utilized in the past beryllium oxide ceramic in between the silicon chip and the metal mounting base of the package in order to achieve a lower value of thermal resistance than for a similar construction made with aluminum oxide. Beryllium oxide is also of use as a structural ceramic for high-performance microwave devices, vacuum tubes, magnetrons, and gas lasers. (Aldinger and *al.,* 2005).

As all other beryllium compounds, beryllium oxide is carcinogenic and may cause chronic beryllium disease. Once fired into solid form, it is safe to handle so long as it is not subjected to any machining that generates dust. (HSDB, 2005)

In summary, the quantities and forms of beryllium in electrical and electronic equipment (EEE) have not led to their identification as a major issue during landfill and waste management, although it should be noted that occupational exposure is a possibility during recycling and reclamation. Since beryllium is not known to be particularly toxic in the environment and because it has only recently been identified as a health hazard in IT and telecommunications equipment due to trends for recycling, it is a reasonable assumption that it is most hazardous when inhaled as a dust or fume. This is released when components are shredded, and from copper-beryllium alloys when metals are heated. If an organization is aware of the risks of beryllium and manages or controls those risks appropriately, the risk to human health is small (Cunningham L D, 2004).

The last subject researched on the current or possible recycling procedures for recycling beryllium oxide and other beryllium compounds proved to be of little use. Demonstrating a great absence of such procedures, in addition to a vast gap in the knowledge of WEEE and hazardous waste recyclers on how to dispose of such products in an environmentally sound manner. In effect, the only process currently implemented in the UK and more widely within Europe is the reselling of beryllium oxide due to its high value, however in cases where economics do not justify the segregation of beryllium oxide waste for resale, as a solid material it may be landfilled if the concentration is low. As a discarded powder, even in low concentration, it must be dealt with at approved hazardous waste disposal sites that are currently scarce if not non-existent in the UK and Europe.

A case study was found specifically based on the recycling potentials of beryllium oxide in WEEE and may be found in Annex 9 provided with this report. The results however positive, were still insufficient to provide a clear solution and therefore inconclusive. Moreover the study has yet to prove whether it constitutes a viable business case, in as much as whether the re-use financial returns would outweigh the costs of the described process transferring Beryllium oxide into Beryllium.

Further studies in this domain are still in process and more are required in order to uncover a feasible solution.

3.2.2 Results and discussions on the identification of the composition of the heat sinks:

The following results were obtained from the attempts of communication with the various companies. The different lists of companies contacted may be found in more detail in Annex 14 accompanying this report.

The main manufacturers whose names did appear on the heat sinks were recorded along with their references in Table 1. The manufacturers able to be identified by these names were contacted regarding the composition of the heat sinks and provided with the various references and pictures of the heat sinks in question (Figure 1).

Names	Results		
Aerial Facilities Ltd	REF 05-002303	S/N 31243	
CCC OR LCC	ND4117-01	S/N 27614M	
EMC	5307		
Ericsson	20284	RC01028044A	
EWC	1301	REP 015101	
FILITRONIC COMTEK	FB-527-1819	S/N 3447	
KDI	No references		
KIK	A3GT22B		
MCR	STM 961-15B	CBC xx 0112	
No name	C PH	BLV 958	H9511, Netherlands
Philips	VFS 891A		
RF Florida	32-1059		
RF Florida	GSM 1800	DNF 2540	T0147
TRAK	I1819/F	DCI 1800	20003-367
TRAK	I1819/F	DCI 1800	199943-308

Table 1: List of names and corresponding references recorded on the heat sinks

The OEMs contacted are listed as follows: Aeroflex Corporation; manufacturers of the KDI heat sinks, Florida RF Labs and EMC technology; manufacturers of RF Florida heat sinks, Ericsson, Philips, Filitronic Comtek Plc., TRAK and Axell Wireless; manufacturers of the Aerial Facilities Ltd heat sinks.

Their responses towards the subject were varied but all negative; Philips were apologetic and regretted to inform me that their technical support could not offer any advice as these products were well beyond their knowledge. They suggested I contact their main switchboard and explain the issue; however the switchboard was unable to provide any further information.

Ericsson replied via Ericsson Nikola Tesla (ETK) and were also unable to provide any confirmation on the composition of the heat sinks. However they informed me that Ericsson products mainly consist of metals possible to recycle, e.g. iron, aluminium, copper and smaller amounts of precious metals. Therefore beryllium oxide, as a risk substance in recycling, had been phased out from Ericsson designed products. They could not assist further.

RF Florida Labs and EMC technologies replied that they do not supply heat sinks as such, but some of their components are mounted on flanges that act as heat sinks. When this is the case they are made from copper, copper tungsten, alumina and in some cases beryllium copper. Beryllium oxide is a material that they utilize to manufacture some of their high power Resistors and Terminations from. They then print or sputter resistive elements onto these substrates. However, the material or substrate used is preformed inert beryllium oxide substrate suitable for printing or sputtering resistive elements and safe to handle and manufacture with. The flanges therefore do not contain beryllium oxide; however certain chips that are mounted may be made from such a substance but none of the parts contain powdered beryllium oxide. Beryllium oxide is not used in the heat sink itself.

TRAK were also able to supply a certain amount of information via Kaelus, a business division of Smiths Interconnect that includes four brands one of which is TRAK. They confirmed that the TRAK heat sinks are old ferrite isolators they supplied to Nokia, now Nokia Siemens Networks (NSN). They also informed me that the heat sinks were manufactured by TRAK between 1999 and 2000. The main housing of the heat sink is aluminium, there are two ceramic magnets and a mild steel, nickel plated circuit plate connecting the top and bottom magnet around the outside of the unit. Inside there are two pieces of ferrite material, most probably Trans Tech Inc. material. Also inside is a beryllium copper centre conductor which is a thin 0.127mm circuit and a beryllium oxide termination. There are a few mild steel discs and screws mounting the whole together. The beryllium oxide contained inside is in solid form, and would only be an issue if it was to be broken or machined into dust.

Axell Wireless supplied me with valuable information regarding the composition of the 05-002603 model. It consists of an aluminium case and lid; the connectors are brass with polytetrafluoroethylene (PTFE) inserts. Internally there is a printed circuit board (PCB) with a single component mounted on. The beryllium oxide component is soldered to the PCB and attached to the case; they also provided a technical sheet of the heat sink (Annex 10). They were adamant that the beryllium oxide should not be in powder form and is encapsulated; the only possibility would be if the termination had received too much power, causing it to blow up, if this was to be the case care must be taken. However they have not come across many in the time they have dealt with their product range. As to the possibility of a tack-back scheme, re-use or recycling of the components, they replied that it was dependent on the condition of the units. They are studying if able to take them back and have still to reply with further details.

Without any references to provide, Aeroflex, were still able to supply a certain amount of information on the KDI heat sinks. After reviewing the pictures, they believe that the product dates from the mid 1990's vintage, or before. They appear to be PPT style heat sinks. They may be a PPT800 which is still only a guess. However, this product would consist of a nickel plated copper housing and a beryllium oxide substrate soldered to the housing using a leaded solder. The beryllium oxide chip would have a nichrome sputtered resistor on it covered by a passivation layer of epoxy paint to protect the resistor, a gold plated beryllium copper tab soldered to the substrate and an alumina cover chip. This assessment is a guess due to the lack of references and based solely on photographs, however, based on this description, the KDI heat sinks contain no powdered beryllium oxide, only as a substrate therefore as a solid.

The brands EWC, EMC, KIK, CCC or LCC and the references of the unbranded heat sinks did not refer to any know companies. Further research on the EMC 5370 uncovered an Engineering Control Drawing (Annex 11) that suggests that they were manufactured by EMC Technology Inc., a company that has ceased to exist. The technical drawing also provides a list of the materials used; only the chip appears to be made of solid beryllium oxide.

It is possible to conclude from the above, that a certain amount of the heat sinks stored at Shields Environmental do not in reality contain powdered beryllium oxide but under solid form and often alloyed to other metals, therefore no longer hazardous. However many other varieties of heat sinks were unable to be identified and warnings of beryllium oxide are visible on certain varieties. Thus the content of the stock at Shields Environmental contains a wide range of varieties with various compositions from hazardous to non-hazardous.

3.2.3 Results and discussion on the reuse and recycling possibilities:

Firstly, the results from making contact with the CR departments of the OEMs in regards to a take-back scheme proved to be of little help. Only Axell Wireless and Ericsson came back with positive replies. Axell Wireless stated that they would be able "recycle/dispose" of these units if required, however when further questioned as to the procedure that would be followed, they have still to provide a response. Furthermore Ericsson confirmed the existence of a take-back scheme that they believe would be able to recycle the Ericsson heat sinks. They have yet to inform me on the process that will be applied to the heat sinks and whether they are able to take back all varieties of heat sinks or just their own production. In the case of only the Ericsson heat sinks being taken back this would imply a prior separation of the heat sinks by brand. This activity could be time-consuming whilst still leaving Shields Environmental with a stock of hazardous and non-hazardous heat sinks to deal with.

Of all the negative responses only TRAK provided a reason as to why. Indeed the products are 100% custom for NSN and therefore unable to be taken back and re-used as the heat sinks.

The results from contacting the various CR departments of most of the major EMC companies provided of very little help. The major companies approached were: Hon Hai Precision Industries (Foxconn Technological Group), Flextronics, Celestica, Sanmina-SCI, Jabil, Elcoteq, Benchmark Electronics, Vanguard EMS Inc., Plexus, Mara Technologies, Kimball Electronics Group, ESCATEC and Electronic Systems Inc. Only two responses were received, both Plexus and ESCATEC looked deeper into the subject. Both companies being unaccustomed to dealing with beryllium compounds were unable to provide any solutions; nonetheless they did provide the names of recycling companies they use.

The list of smaller EMC companies contacted is as follows: Multek, ABSCO Materials, Goodfellow, Panreac, GS Nordic, EMS Ltd, Briton EMS and Dynamic EMS. The results provided were of a similar nature as the ones from the major EMCs. Only two companies replied. ABSCO Materials informed us that none of the products they are able to handle contain beryllium oxide. They advised us to contact Materion, a producer of beryllium oxide. Brinton EMS replied that beryllium does occur in certain products the handle, possibly also alloyed with copper. If they were to dispose of such products they would send it through their waste route already in place with an electronics waste disposal company Veolia. However they have never had to deal with products containing powdered beryllium oxide and could be of no further assistance.

Furthering the enquiry, the few existing producers of beryllium oxide and other beryllium compounds were approached; The companies approached are: Ulba, Brush Wellman, Materion, NGK Berylco, Ulba Shine, BeST and American Beryllia.

Materion, one of the major producers and users of beryllium compounds including beryllium oxide did investigate into the matter further. After having discussed the matter with their US branch, they replied that currently they are only able to recycle bare beryllium oxide substrates. They manufacture beryllium oxide materials and components and can recycle such materials; however, they are not a specialist recycling company and are not capable of dealing with other materials present in the heat sinks. They cannot recycle metallized beryllium oxide substrates as the metallization is unsuitable for their process. Work is currently taking place at their Tucson, Arizona facility where new recycling methods are being implemented and may result in the expansion of their recycling capabilities at some time in the future. However they currently can only recycle bare beryllium oxide ceramics. In addition they are not a registered waste disposal organization and therefore not permitted to dispose of the heat sinks, they may only dispose of their own waste.

America Beryllia replied that they could not deal with such a large volume of waste to recycle. NGK Berylco only supply beryllium copper alloys and have no process in place to recycle beryllium oxide and Ulba have no interest in beryllium oxide and know of no recycling procedures.

The following results summarize the responses from companies that use or could possibly use beryllium oxide or beryllium. The list of companies approached may be found in Annex 12.

Smelters and sinters such as Aldel replied that they are a primary smelter, which signifies that they produce primarily aluminium from alumina and only recycle scrap-aluminium from known partners. They further informed me that beryllium used in aluminium alloys is used as a metal never as an oxide and therefore little hope of a solution was to be expected from smelters. However a possibility may be to search a company that produces aluminium-metal alloys which are used for alloying by aluminium-smelters. The copper and aluminium could then possibly be used at once without the need to separate them. Following this advice, aluminium-metal alloy producers were also contacted.

Hydro replied that re-melting aluminium could contain other elements as part of the alloying process. However, large quantities of copper and/or ceramic materials would have to be removed prior to re-melting. Thus they could not assist further until the heat sinks were dismantled into separate elements. In addition, Talum are unaccustomed to dealing with beryllium compounds and could not assist further.

Rio Tinto is currently a re-melt operation that purchase primary aluminium from the London Metal Exchange that they re-melt and alloy with silicon and magnesium and then cast as billet for the extrusion industry. They replied that their initial concern, other than toxicity, is the ability to dissolve the beryllium oxide in aluminium due to its high melt point. They operate at 720 degrees Celsius at which temperature beryllium oxide would at best be a suspended solid. They have no experience of working with this type of material and would usually treat it as a contaminant as any other oxides that arise in their preparation process by removal through a degassing unit and filtration. In theory their systems would be able to filter out the beryllium oxide. In reality however the toxicity of the beryllium oxide would be an issue. In effect they dispose of insufficient scrubbing systems that could not cope with the emissions therefore not meeting the environmental standards necessary to maintain their operating license. They would also not be able to process the beryllium oxide and are concerned that any particles that the filter failed to contain would find itself in the finished product as an 'inclusion' that would damage the extruders die.

The following results were received from metal and alloy producers. Knight Strip Metals replied that they do have an involvement with beryllium in that they process and supply a copper beryllium alloy. All the same this is in the form of strip metal and the beryllium content is only 2% and could therefore not assist further. IBC Advanced alloys in regards to the enquiry forwarded the information to a company which deals with beryllium oxide however no response has been received. IBC Advanced alloys do not themselves buy beryllium oxide; they only deal in pure beryllium or beryllium copper. Kaiser Aluminium cannot currently support heat sinks. AWA Refiners are also not able to deal with beryllium compounds. They only purchase precious metals such as gold, silver etc. and items containing these precious metals. Furthermore Goodfellow were unable to help with any information on the recycling of beryllium oxide and advised us to contact Cleanaway, who were also unable to assist. All other companies having an interest in beryllium oxide and who were contacted could not assist.

After searching companies that had a need for beryllium oxide, recyclers specialized in WEEE and/or hazardous wastes were approached. The list may be found in Annex 13.

Many negative responses were received. After discussing with their specialists Alcoa were unable to help with our request. Whereas they are very interested in recycling and reusing aluminium and materials from electronics, they are not working on the recycling of metals containing beryllium. In addition, as beryllium oxide is not something Total Waste Management Ltd are able deal with, they suggested contacting Williams Environmental Ltd who have still to response. Recycling lives also provided the same response as did The Recycling People, Enviroco, and Paper Round.

TCG Recycling were sorry to inform me that electronics or components containing beryllium oxide are not items that they can accept. In effect all electronics that proceed through their process are carefully screened for beryllium oxide and sent back to the customer or to a permitted hazardous waste facility if present as it poses health and safety hazards when processed through their methods. To date they have not found any recycling options for components containing beryllium oxide. The hazardous waste facilities they provided us with were unable to help in the recycling of heat sinks.

One positive response was received form Seven Ways who have confirmed that they are able to deal with the heat sinks. They could be removed from site where they would be separated into their individual parts and safely disposed of; the necessary paperwork would then be issued. The beryllium oxide would not need to be removed from the components. Further information has been requested on the process as to how the heat sinks would be recycled however I am still awaiting the details.

3.2.4 <u>Conclusion:</u>

Currently the responses provided concerning my enquiry do not indicate a possible solution as of yet to the recycling or re-use of the heat sinks stored at Shields Environmental. Various companies have yet to reply back to me. The possible solutions provided by Ericsson and Axell Wireless if only applicable to their specific heat sinks, the issue of recycling the other heat sinks would still persist. I have tried many times to follow-up the companies claiming they are capable of dealing with the heat sinks however without any great success. In regards to current research projects and my findings, there is hope for a solution in the near future.

A future recommendation would be to continue to follow-up the companies claiming to be adequately equipped to deal with such products. An additional recommendation would be to keep in contact and updated with the new favorable methods certain recyclers may develop particularly larger recyclers and producers such as Materion. The same can be said for current research projects and studies which may provide a viable solution.

4 Conclusion:

The environmental legislation research for the various different countries produced a comprehensive report of information specifically researching the import and export regulations for commodities such as EEE and the same regulations for WEEE in addition to recycling regulations for such products. Thus providing Shields Environmental with the necessary information concerning their main points of interest and any relevant information that could prove useful at a future date when dealing within these target countries.

The national and local legislation of most if not all of these countries is not being fully implemented. It would be wise, once within the country to seek expert advice as verification that all aspects have been covered and correctly dealt with. This would guarantee Shields Environmental full compliance with such legislation.

The difficulties faced were all of the same nature for all the countries. The access to correct and up-to-date information proved difficult to find as little or no help was provided by the different government departments. Also, I found the comprehension of most of the legal documents complex, mainly due to the shear amount of laws and regulations and the fact that many contradict each other. Having no previous legal knowledge or background I lacked specific vocabulary however I do believe to have created well researched and detailed reports that will provide Shields Environmental with the information they require. This specific project gave me with the opportunity to accumulate a basic legal vocabulary and a first-hand view of the legislation involved in such activities. I was also able to improve my organisation skills and acquire a more methodical manner of dealing with such subjects.

The search for a sustainable solution for the stored heat sinks although unsuccessful in the resolution of the issue provided vital information. Shields Environmental now has the information concerning the composition of various varieties of heat sinks, is able to explain the different routes explored and the numerous companies contacted. A future recommendation would be to continue to follow-up with recyclers such as Seven Ways who claim to be able to deal with such products. The same applies to Ericsson and Axell Wireless in regards to their take-back schemes and capability to recycle their specific heat sinks. Nonetheless this solution would still leave the other varieties of heat sinks to be dealt with; therefore this issue would still persist.

An additional recommendation would be to keep in contact and updated with the new favourable methods certain recyclers may develop particularly larger recyclers and producers such as Materion. The same can be said for current research projects and studies which may provide a viable solution that could be undertaken by Materion or similar companies. The interest being that the method could also apply to their products that they are currently unable to recycle. On this subject, Materion has been approached with the information concerning the study on the Recyclability Potentials of Beryllium Oxide from E-waste Items in Nigeria by Onyenekenwa Cyprian Eneh, however they replied that the study would not change their processes in the short term but the information could prove useful in evaluating processes for the future. They therefore are still unable to assist further. Another option could be to separate all the heat sinks by model and brands enabling to distinguishing non-hazardous categories from hazardous. In effect, the categories not containing powdered beryllium oxide are able to be recycled by recyclers or even by possibly smelters or sinters. Nevertheless this choice would still leave Shields Environmental with a stock of heat sinks either unable to be identified and therefore of an unknown composition or with definite hazardous heat sinks containing powdered beryllium oxide. The proportions of unidentifiable heat sinks is not known, however an overall review of the stock permits to estimate that 50% or more are of an unidentifiable composition.

A more favourable solution would be one that could be applied to all the heat sinks in question. Thus I would advise Shields Environmental to continue their search focusing particularly on recyclers. I would also advise to continue researching new methods and studies that could be applicable and approach major producers such as Materion with these new methods. They would be most interested as it may also apply to their various products that the currently are unable to recycle. Keeping in close contact with companies similar to Materion would also be of interest as they may discover a recycling method that could apply to the heat sinks at Shields Environmental.

A difficulty faced during the project was the lack of knowledge I started off with, I received great help form various members of staff however their knowledge of the heat sinks was little as the issue had never truly been looked into. I found it difficult at first to figure out from what angle it would be best to deal with the issue. I decided to deal with it methodically, using a step by step method that would enable me to subdivide the issue into smaller more manageable sections. From this project I was able to exploit various ideas and act on my initiatives giving me a sense of responsibility I greatly appreciated.

The work placement at Shields Environmental was extremely rewarding and beneficial for my future studies. I discovered the works of an expanding UK company and was able to observe and be involved in various sides of the business. The experience gained has confirmed my desire to work within a company on sustainable development and environmental management. It has also provided valuable experience that I am positive will greatly help during my studies of sustainable development and management at La Rochelle Business School.

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Résumé

During the three month placement at Shields Environmental, I was entrusted with various projects. One of these projects consisted in researching the current environmental legislation in Brazil, Argentina, India, Malaysia, Russia, China and South Africa. This research was to focus on two main domains: Electrical and Electronic Equipment (EEE) and Waste Electrical and Electronic Equipment (WEEE). I was to research the import, export and transit regulations for EEE and WEEE, in addition to the recycling regulations for WEEE. As a result of this research, country-specific reports were complied. A second project I was entrusted with was to find a sustainable solution for heat sinks containing powdered beryllium oxide currently stored at Shields Environmental. The first step taken was to research the elements I was to deal with. I then identified, when possible, the composition of the heat sinks to confirm that they did indeed contain powdered beryllium oxide. From this various potential companies who may know of a sustainable solution were contacted. As of yet a solution is still to be found however several potential leads are still being explored.

Keywords: environmental legislation, EEE, WEEE, beryllium oxide, heat sinks, sustainable solution