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Hazardous waste management in Chilean main industry: An overview

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Abstract

The new "Hazardous Waste Management Regulation" was published in the Official Newspaper of the Chilean Republic on 12 June 2003, being in force 365 days after its publication (i.e., 12 June 2004). During the next 180 days after its publication (i.e., until 12 December 2004), each industrial facility was obligated to present a "Hazardous Waste Management Plan" if the facility generates more than 12 ton/year hazardous wastes or more than 12 kg/year acute toxic wastes.

Based on the Chilean industrial figures and this new regulation, hazardous waste management plans were carried out in three facilities of the most important sectors of Chilean industrial activity: a paper production plant, a Zn and Pb mine and a sawmill and wood remanufacturing facility. Hazardous wastes were identified, classified and quantified in all facilities. Used oil and oil-contaminated materials were determined to be the most important hazardous wastes generated. Minimization measures were implemented and re-use and recycling options were analyzed. The use of used oil as alternative fuel in high energy demanding facilities (i.e., cement facilities) and the re-refining of the used oil were found to be the most suitable options. In the Zn and Pb mine facility, the most important measure was the beginning of the study for using spent oils as raw material for the production of the explosives used for metals recovery from the rock.

In Chile, there are three facilities producing alternative fuels from used oil, while two plants are nowadays re-refining oil to recycle it as hydraulic fluid in industry. In this sense, a proper and sustainable management of the used oil appears to be promissory.

Keywords: Chilean industry; Hazardous wastes; Recycling; Reuse

1. Introduction

Chilean solid waste generation sources can be divided into household (46%), industry (16%), construction (37%) and hospitals (1%) [1]. Recent estimations indicate a generation of about 3,000,000 ton/year (0.55 kg inh^{-1} day^{-1}) of industrial solid wastes [2]. These industrial wastes are mainly handled by Hidronor (43%), Bravo Energy (30%) and other companies (27%). On the one hand, Hidronor is an industrial and hazardous wastes management company that performs two main treatment processes: immobilization of wastes and production of alternative fuels (from used oils). In addition, Hidronor handles industrial wastewaters and also operates a hazardous waste landfill. On the other hand, Bravo Energy is the main Chilean company producing alternative fuels, mainly handling used oils and organic solvents as raw materials.

From the 3,000,000 ton/year industrial wastes, a generation of 129,918 ton/year hazardous wastes has been reported (0.024 kg inh^{-1} day^{-1}) [1], being mining, chemical, mechanical and pulp and paper industry the main important sources of these wastes (see Table 1).

Nowadays, Chilean industrial hazardous wastes are mainly immobilized and landfilled (Hidronor), used as raw material (used oil and spent solvents) for alternative fuels production (in Hidronor and Bravo Energy), used as raw material (used oil) for re-refining oil (in Futuroil), while healthcare wastes are mainly incinerated or sterilized in Procesan, the most important Chilean healthcare wastes management facility. Nevertheless, an important fraction of industrial hazardous wastes is still mixed with non-hazardous wastes, being mainly landfilled and producing serious environmental impacts regarding heavy metals and persistent organic pollutants content in landfill leachate. In this sense, splitting strategies for hazardous wastes recovery are needed in Chilean industry that may reduce the disposal rate of these wastes in communal landfills and impulse resource recovery and recycling of valuable materials of these wastes.

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Table 1
Hazardous waste generation in Chilean industry

Industry	Generation	
	(ton/year)	(%)
Mining	52,225	40.2
Chemical	19,432	15.0
Mechanical	18,405	14.2
Pulp and paper	12,744	9.8
Steel	11,108	8.5
Painting	8,483	6.5
Mineral oil	6,400	4.9
Glass	1,121	0.9
Total	129,918	100

The new "Hazardous Waste Management Regulation" [3] was published in the Official Newspaper of the Chilean Republic on 12 June 2003, and put into force 1 year after its publication. The next 180 days after its publication (i.e., until 12 December 2004) were set as the deadline to present a compulsory "Hazardous Waste Management Plan" for each industrial facility with a yearly hazardous waste generation rate of more than 12 ton/year, or more than 12 kg/year acute toxic wastes [3]. The new regulation defines four characteristics for the hazardous wastes: toxicity (acute, chronic and extrinsic), inflammability, reactivity and corrosiveness. Acute toxicity is mainly related with specific compounds present in wastes that can cause death to human beings in small doses (e.g., arsenic oxides such as As_2O_5 and As_2O_3). Chronic toxicity is related with wastes that contain substances that can cause accumulative toxic effects, carcinogenic effects, mutagenic effects and teratogenic effects in human beings (e.g., 2,4,6-trichlorophenol). Extrinsic toxicity is associated with the leachability of toxic (acute and chronic) compounds present in wastes and is related to the maximum permissible concentration of the compound in the leachate (e.g., lead, 5 mg/L). Inflammability of a waste is related to four main characteristics: the waste is a liquid with an inflammation point under 61 °C; the waste is not a liquid and can provoke, under standard pressure and temperature (1 atm and 25 °C), fire by friction, by water absorption or spontaneous chemical changes. Finally, reactivity is associated with the following waste properties: the waste reacts strongly with water and can cause explosive mixtures with it. The waste contents cyanides and sulphurs that can produce toxic gases in a pH range between 2 and 12.5. Corrosiveness is mainly attributed to a liquid waste with a pH value less than 2 or more than 12.5, or if the waste can corrode steel (SAE 1020) at a minimum rate of 6.35 mm/year at 55 °C.

In addition, the regulation distinguishes hazardous wastes in three types defined in the complementary lists. List 1 includes healthcare wastes, some pharmaceutical wastes and wastes from biocides production, among others, List 2 includes metal-containing wastes and other toxic compounds, and List 3 includes other hazardous waste types, like used catalysers, packing of toxic substances and some contaminated soils, among others. The new regulation also includes some topics about waste generation, inducing the generator to separate the different waste streams inside the facility (hazardous/non-hazardous). Moreover, it also includes in this section some topics about waste minimization in the source, as well as possible reuse and recycling of wastes. The regulation includes a separate section of hazardous waste storage, focused on avoiding possible environmental impacts by the storage of chemical-compatible residues as well as indicating the basic storage facility constructions guidelines. A separate section about hazardous waste transport is also included in this new regulation. It indicates the type of vehicles capable to transport hazardous wastes, as well as the training level of the drivers and personnel. It also includes a specific action plan for transport accidents. In addition, the regulation includes a complete chapter about the elimination facilities suitable to handle hazardous wastes, including several indications about the engineering project of these facilities. It also includes technical specifications for hazardous waste landfills and incineration facilities, based on the introduced new regulation.

The Chilean gross internal product (GIP) accounted in 2004 for about 95,065 million US$, being the mining, forest and fishing industry the most important sectors, contributing with a 7.9; 3.3; and 2.9% of the Chilean GIP [4].

In this sense, hazardous waste management plans were carried out in three facilities that represent three of the most important sectors of Chilean industrial activity: a paper production plant, a zinc (Zn) and lead (Pb) mine, and a sawmill and wood remanufacturing facility. Hazardous wastes were identified, classified and quantified according to the new regulation, and minimization measures were implemented and reuse and recycling options were analyzed.

2. Methodology

Hazardous wastes were identified and quantified in all industrial facilities according to the new "Hazardous Waste Management Regulation" [3]. In Fig. 1 the hazardous waste identification methodology is explained.

First, waste composition was checked against List B, which includes all the wastes considered as non-hazardous. If the waste were included, it was immediately considered as non-hazardous and if it were not included in this list, the waste was checked in List A. Since List A contains all the wastes and waste components considered as hazardous, if the waste was present in this list, it was considered immediately as hazardous. If not, the waste and its components were checked in List I–III. List I includes all the health care wastes, pharmaceutical wastes, and other groups like oil and hydrocarbon emulsions, among others. List II includes mainly heavy metals, metallic compounds and organic solvents and List III includes other wastes like catalysers, packaging of hazardous substances and contaminated soils, among others. If the waste or its compounds were included in one of these lists, the waste was considered to be hazardous. If not, the waste was checked in the lists of Articles 88 and 89 of the regulation. Article 88 includes all the substances and chemical compounds considered as acute toxic compounds, while Article 89 includes all the chronic toxic compounds. So if one component of the analyzed waste was present in Article 88 or

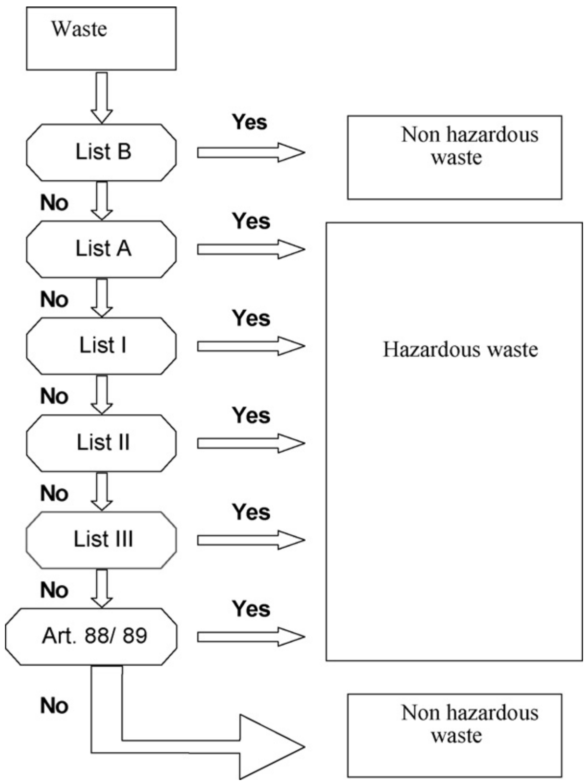

Fig. 1. Hazardous waste identification methodology.

89, the waste was considered hazardous. If not, the waste was considered as non-hazardous.

Hazardous wastes were quantified in all cases. For quantification purposes, each production facility was separated into different areas. In all of these areas, hazardous wastes were weighed or quantified by statistical information.

Finally, a hazardous waste management plan was elaborated for each industrial facility, including waste minimization recycling and reuse, transport, treatment and safe disposal.

3. Case study in a Chilean paper industry

The data reported in this case study was adapted and summarized from González [2] and Navia et al. [5].

3.1. General description of the paper production plant

The paper production plant is located in Santiago de Chile (Metropolitan Region) and produces about 260,000 ton/year, using about 260,000 ton/year recycled paper and 50,000 ton/year cellulose as raw materials. The facility was divided in four main areas to facilitate hazardous waste identification and quantification, as shown in Table 2. The production starts with the recycled paper mechanical pulping process, where the fiber is redissolved, deinked and cleaned for further paper production. The deinking sludge is pumped to the wastewater treatment plant, and the produced wastewater treatment sludge is considered not hazardous, being disposed in a municipal landfill. Then, the dissolved fiber goes to the 5 different paper-producing machines, for producing 11 different types of paper. Finally, in the conversion area, the paper rolls are cut and rewind, to obtain a apar quality as indicated by each standard.

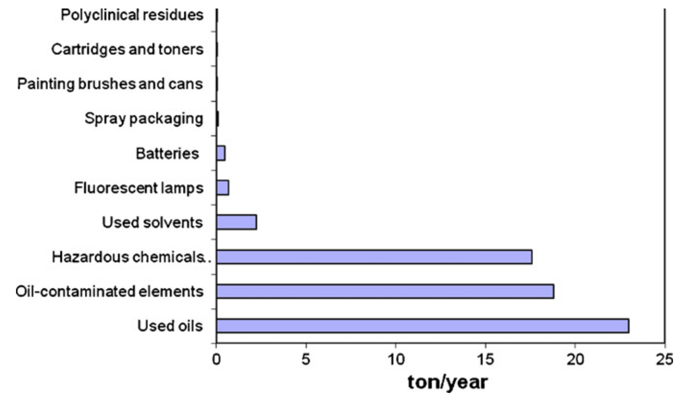

Fig. 2. Hazardous waste generation in the paper production facility.

At the time of the study, all the hazardous wastes from the company were disposed internally and in a municipal solid waste landfill.

3.2. Hazardous waste identification and quantification

In Table 3, a summary of the main hazardous wastes identified in the plant is given. As shown in Fig. 2, used oils and oil-contaminated elements are the main hazardous wastes identified in the plant, with a generation of 23.0 and 18.8 ton/year, respectively from a total generation of 62.9 ton/year. As shown in Table 3, used oils were classified as inflammable and toxic residues. On the one hand, some used oils did have an inflammation point below 61 °C and on the other hand, the presence of heavy metals was also detected. Another important hazardous waste identified were the hazardous chemicals packaging, with a generation rate of 17.6 ton/year.

Table 2
Main and sub-areas of the paper production facility

Main area			
Administration	Production	Conversion	Maintenance and services
Sub-areas			
Offices	Paper production	Cutting	Maintenance
Laboratories	Recycled paper treatment	Rewind	Storage
Restaurant			Vapor plant
Polyclinic			Industrial water plant
Transport			Wastewater treatment plant; compressed air plant

Table 3
Hazardous waste generation in the main and sub-areas of the paper production facility

Hazardous waste	Hazard	Sub-area/main area
Used oils	Inflammable–toxic	Maintenance/maintenance and services; paper production/production
With oil-contaminated elements	Inflammable	Maintenance/maintenance and services
Hazardous chemicals packaging[a]	Corrosive	Maintenance/maintenance and services; paper production/production; laboratories/administration
Used solvents[a]	Inflammable–toxic	Maintenance/maintenance and services
Fluorescent lamps	Toxic	Storage, maintenance/maintenance and services; offices/administration
Batteries	Corrosive–toxic	Maintenance/maintenance and services
Spray packaging	Inflammable	Maintenance/maintenance and services; recycled paper treatment/production; offices/administration
Painting brushes and cans	Inflammable	Maintenance/maintenance and services
Cartridges and toners	Toxic–inflammable	Offices/administration
Polyclinical residues	Toxic	Polyclinic/administration

[a] Specific hazardous wastes from the paper industry.

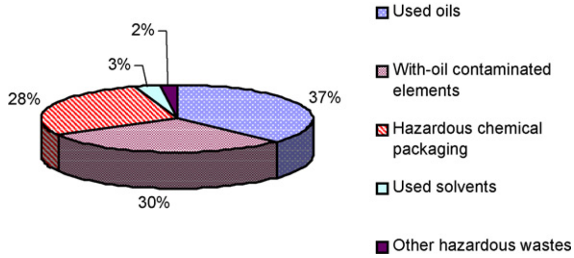

Fig. 3. Main hazardous waste streams in the paper production facility.

The main hazardous wastes identified in the facility were non-specific paper industry hazardous wastes, i.e., wastes that most industrial sectors may produce (e.g., used oils). Nevertheless, hazardous chemicals packaging and used solvents were identified as specific paper industry hazardous wastes. In fact, hazardous chemicals packaging is referred to colorant packaging, bleaching agents packaging, dispersant and fixing agents packaging and microbiocides packaging. In addition, used solvents like perchloroethylene are typical solvents used in the paper industry for correctly cleaning paper machines.

Looking Fig. 3, used oils account for the 37% of the total generated hazardous wastes in the plant, while the oil-contaminated elements, hazardous chemicals packaging and used solvents represent the 30, 28 and 3% of the total hazardous wastes generated, respectively. Finally, "other hazardous wastes" (which include polyclinical residues, cartridges and toners, painting brushes and cans, spray packaging, batteries and fluorescent lamps) account for only a 2% of the total hazardous wastes generated.

In addition, as shown in Fig. 4, the maintenance and services area produces the 70% of the total hazardous wastes, while production and administration areas generate 19 and 11% of the hazardous wastes, respectively. The main hazardous wastes generated in the maintenance and services area are used oils, oil-contaminated elements and used solvents (see Table 2 and Fig. 2).

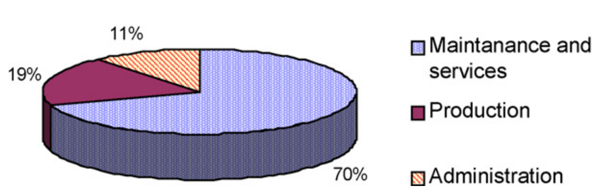

Fig. 4. Hazardous waste generation in the different paper production facility areas.

3.3. Hazardous waste management plan in the paper production facility

In the case of used oils, it was recommended to perform a periodical quality analysis in all the production equipment and machinery for preventing early oil changes. A waste segregation was also recommended in this case, thus, preventing oil contamination of non-contaminated elements. Oil-contaminated paper should be recycled in the facility after a previous technical study. The main reuse proposed for the used oils was their elimination in authorized plants for their use as alternative fuel. The cement industry was established as the most practical facility for this kind of reuse, as almost all these plants have the environmental permission to do it. Another interesting proposed alternative was the re-refining of the used oil in plants like Futuroil, which are able to produce a high standard lubricant using spent oil as raw material. In the case of hazardous chemicals packaging, it was recommended that these materials should be recycled to the supplier, for a possible reuse. In the case of solvents, periodical cleaning of all the equipments and their parts was suggested for minimizing their use, coupled with their replace by more environmental friendly solvents when possible. Finally, the elimination of these wastes in authorized facilities for the production of alternative liquid fuels, like Bravo Energy was recommended. For batteries, fluorescent lamps, cartridges and toners was recommended the disposal in Hidronor, a facility that is allowed to produce an inert solid waste after a mixing process, which is then safely disposed in a hazardous waste landfill.

4. Case study in a Chilean zinc and lead mining facility

The data reported in this case study was adapted and summarized from Lagos [6] and Navia et al. [5].

4.1. General description of the Zn and Pb mining facility

The Zn and Pb mining facility is located 120 km to the Norwest of the city of Coyhaique (XI Region, in Southern Chile).

Table 4
Hazardous waste generation in the Zn and Pb mining facility

Hazardous waste	Hazard	Generation area
Used oils	Inflammable–toxic	Maintenance/mine/plant equipment/vehicles
Clay crucibles	Toxic	Laboratory
Empty drums used for hazardous waste containment	Toxic–inflammable–corrosive–reactive	Maintenance/mine/plant equipment/vehicles
With hydrocarbons contaminated soil	Inflammable–toxic	Maintenance/mine/plant equipment/vehicles
Hydraulic hoses contaminated with hydrocarbons	Inflammable	Maintenance/mine/plant equipment/vehicles
With oil-contaminated elements	Inflammable–toxic	Maintenance/mine/plant equipment/vehicles
Mineral oil-contaminated with water	Inflammable	Maintenance/mine/plant equipment/vehicles
Oil filters	Inflammable	Maintenance/mine/plant equipment/vehicles
Lead batteries	Corrosive–toxic	Maintenance/vehicles
Used greases	Inflammable	Maintenance/mine/plant equipment/vehicles
Used solvents	Inflammable–toxic	Concentration plant
Painting brushes and cans and spray packaging	Inflammable	Administration offices/personal houses reparation and maintenance

The mine uses room and pillar technology for processing about 1500 ton/day (wet basis) of mineral. After the extraction, the mineral is stored for further concentration. The concentration process involves a crushing process, followed by a milling process. Then, the mineral is transported to the flotation process using Denver 30 SUB A cells. The concentrate goes then to three thickeners, and after that to a final filtration process to produce 200 ton/day (dry basis) of a Zn and Pb concentrate. This product is exported and used in the production of paints, car components, construction covering, batteries and medicine.

At the time of the study, all the hazardous wastes from the company were disposed in an adapted landfill in the plant, and all the residues from the concentration step were transported to the mining tailing pond.

4.2. Hazardous waste identification and quantification

The main hazardous wastes identified in the mining facility are described in Table 4. The areas of maintenance, mine, plant equipments and vehicles were identified as the main generators of hazardous wastes. In addition, the laboratory, concentration plant and administration offices, as well as the personnel houses reparation and maintenance, generate important amounts of hazardous wastes (Fig. 5). Used oils account for the 83.2% of the total generated hazardous waste, with 64.6 ton/year out of 77.6 ton/year. Finally, there were other hazardous wastes identified like fluorescent lamps, polyclinical residues, Ni–Cd batteries, cartridges and toners, but they only account for the 0.15% (0.12 ton/year) of the total generated hazardous wastes.

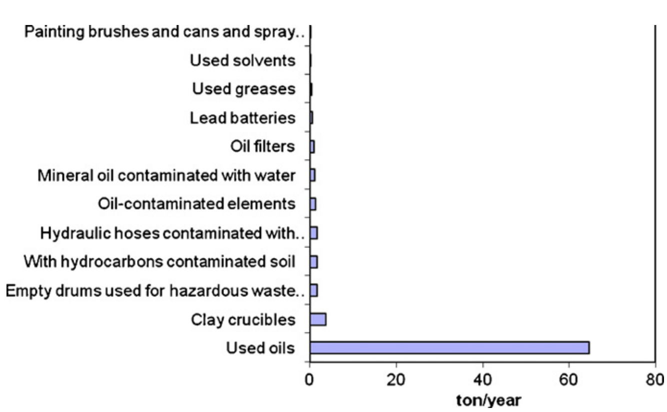

Fig. 5. Hazardous waste generation in the Zn and Pb mining facility.

It is important to remark, that all the hazardous wastes identified were non-specific Zn and Pb mining hazardous wastes. In this sense, it is relevant to highlight that acid tailings (and tailing ponds) containing hazardous compounds, as well as melting slags are not considered as hazardous wastes in the Chilean new "Hazardous Waste Management Regulation". This decision was made of course at a political level and not at a technical one, knowing that tailing ponds are in Chile (a traditional mining country) one of the most important environmental passives to be remediated in the future.

4.3. Hazardous waste management plan in the mining facility

The hazardous waste management plan was more complicated in this case, as there is no authorized facility in the XI Region of Southern Chile to manage, treat and eliminate hazardous wastes. Only Pacific Star is recently designing a hazardous waste landfill, which must first obtain all the environmental permission previous to its start-up.

The separation of all the waste streams for possible waste reuse was implemented in the mining facility. In this case, the most important measure was the beginning of the study for using spent oils in the mining facility as raw material for the production of the explosives used for metals recovery from the rock. For this purpose, it was recommended that the plant should obtain the respective environmental permissions to storage hazardous wastes in the facility. It was evaluated that the hazardous wastes could be transported twice a year to authorized disposal facilities in the center of the country. Finally, it is important to mention that mining tailing ponds are not considered as hazardous wastes in the new "Hazardous Waste Management Regulation" of the Chilean Republic.

5. Case study in a Chilean sawmill and wood remanufacturing facility

The data reported in this case study was adapted and summarized from Vielma [7] and Navia and Vielma [8].

5.1. General description of the sawmill and wood remanufacturing facility

The industry is one of the largest sawmills and wood remanufacturing facilities in Chile, with three sawmills in operation (Mulchén, Bucalemu, and Nacimiento) and one wood remanufacturing plant which also includes the general maintenance and reparations department of the four plants. In the sawmills, wood stubs go to the debarking step, for further classification and storage. During storage, stubs are sprinkled with water to avoid fungi growth. After this, the wood stubs are sawed, impregnated with anti-stain and/or fungicide agents, before entering a final drying process.

In the wood remanufacturing plant, the wood is brushed and classified in different qualities for a further breaking process. Here, cutstocks and blocks a separated and the blocks are used to produce 5 m long blanks using finger unions. Finally, the cutstocks and blanks are used as raw material to produce mouldings and laminated products. The products of the facility are marketed in the U.S.A. (50%), Japan (25%), Korea (10%) and in the Chilean internal market (15%).

A complete identification, classification and quantification of the hazardous wastes generated in the mentioned facility was performed, as well as sustainable storage, management, recycling, reuse, transport, treatment and disposal methods were proposed for each of the four plants. At the time of the study, all the hazardous wastes from the company were disposed in a municipal solid waste landfill.

5.2. Hazardous waste identification and quantification

Hazardous wastes were identified and classified as toxic, inflammable, corrosive and reactive, according to the new Chilean "Hazardous Waste Management Regulation" (Fig. 1). Used oils, oil-contaminated elements, oil drums and anti-stain chemicals packaging were identified as the main hazardous waste streams (Table 5).

Anti-stain chemicals packaging were identified as specific sawmill facilities hazardous wastes. Anti-stain chemicals packaging refer mainly to packaging containing wood antifungal compounds, which are based on copper formulations.

The item "others" was mainly composed by cartridges and toners, fluorescent lamps, batteries and spray packaging. In addition, the total hazardous wastes generation was 38,179; 54,021; and 47,061 kg/year for sawmills Mulchén, Bucalemu and Nacimiento, respectively, more than the 12,000 kg/year established by the "Hazardous Waste Management Regulation" as the minimum for the development of a hazardous waste management plan in an industrial facility. That means, that an integral hazardous waste management plan was developed for the three sawmills of the company.

Used oils and oil-contaminated elements were identified as the main hazardous wastes generated in the remanufacturing facility, while used solvents, diluents and refrigerants were the main hazardous wastes generated in the maintenance and reparations department (see Table 6).

Regarding specific wood remanufacturing facilities hazardous wastes, deoxidant and catalyzer packagings were identified as the most important hazardous wastes. Deoxidants are typically used in cutsocks and blanks production, while catalyzers are used in the manufacture of painted moldures and panels.

5.3. Hazardous waste management plan

First, the wastes were separated in origin into hazardous and non-hazardous. Non-hazardous were also separated into recyclables, non-recyclables and domiciliary. The minimization strategy was mainly focused on the periodical quality analysis for preventing an early oil change in all the production equipments and solvent dosage planning to avoid losses. In addition, aqueous solvents, when possible, replaced chlorinated solvents. The final destination of hazardous wastes was decided as follows: treatment plants for immobilization and authorized landfill and suppliers (paint, oil, grease and anti-stain packaging). Recyclable wastes like paper and cardboard, plastics and metals, were

Table 5
Hazardous waste generation in Mulchén, Bucalemu, and Nacimiento sawmills (kg/year)

Hazardous waste	Hazard	Mulchén	Bucalemu	Nacimiento
Used oils	Inflammable–toxic	3,744	0	3,000
With oil-contaminated elements	Inflammable	6,484	3,375	5,173
Anti-stain chemicals packaging[a]	Toxic	3,232	6,334	7,212
Used solvents, diluents[b] and refrigerants[b]	Inflammable–toxic	1,353	0	535
Oil drums	Inflammable	18,168	40,246	18,667
Hydraulic and pneumatic elements and pieces	Inflammable	2,414	792	540
Painting brushes and cans	Inflammable	972	917	3,310
Diluents cans	Inflammable	249	197	6,718
Others		1,563	2,160	1,906
Total		38,179	54,021	47,061

[a] Specific hazardous wastes from sawmill facilities.
[b] Containing halogenated organic compounds.

Table 6
Hazardous waste generation in the remanufacturing facility and maintenance department (kg/year)

Hazardous waste	Hazard	Remanufacture	Maintenance
Used oils	Inflammable–toxic	1,680	0
With oil-contaminated elements	Inflammable	3,720	34
Used solvents, diluents[a] and refrigerants[a]	Inflammable–toxic	0	64,800
Oil drums	Inflammable	384	0
Solvent drums	Inflammable	768	0
Grease drums	Inflammable	229	0
Diluents cans	Inflammable	45	0
Batteries	Toxic	102	38
Others[b]		1,078	23
Total		8,006	64,895

[a] Containing halogenated organic compounds.
[b] Includes deoxidant and catalyzer packagings, considered specific hazardous wastes from wood remanufacturing facilities.

marketed in the near surroundings. The main sub-products of the sawmill were identified as bark, sawdust and shaves, which are used as fuel in plant boilers.

6. Conclusions

The new "Hazardous Waste Management Regulation" has pushed the industrial generators to make efforts to manage hazardous wastes in the right form, being separation, minimization, recycling and reuse the four main options recommended for a sustainable hazardous waste management. After considering these four options, treatment and safety disposal are of course also included in hazardous waste management plans.

In all cases, used oil and oil-contaminated materials were determined to be the most important generated hazardous wastes. The use of used oil as alternative fuel in high energy demanding facilities (i.e., cement facilities) and the re-refining of the used oil were found to be the most suitable options. In Chile, there are three plants producing alternative fuels from used oil (Hidronor, Bravo Energy and Coactiva), while two plants are nowadays re-refining oil to recycle it as hydraulic fluid in industry (Futuroil and Castaneda Hnos.).

In this work, at the paper production facility, used oils, oil-contaminated elements, hazardous chemicals packaging and used solvents were identified as the main hazardous wastes generated. In the case of used oils, quality control analysis for preventing an early oil change in all the production equipments was recommended, coupled with their elimination in authorized plants (like in the cement industry) as alternative fuel. As an alternative, the re-refining of the used oils in plants like Futuroil (Santiago) seems to be a sustainable waste management option. In the case of hazardous chemicals packaging, the recommendation of recycling these materials to the supplier for a possible reuse seems to be the most feasible. For used solvents, periodical cleaning of all the equipments and their parts was suggested for minimizing their use, coupled with their replace by more environmental friendly solvents when possible. Finally, the elimination of these wastes in authorized facilities for the production of alternative liquid fuels, like Bravo Energy was recommended. For the other hazardous wastes produced in the paper production facility (like batteries, fluorescent lamps, cartridges and toners) their disposal in Hidronor (Santiago) seems to be the more sustainable way of management. This facility is allowed to produce an inert solid waste after a mixing process, which is then safely disposed in a hazardous waste landfill.

In the case of the Zn and Pb mining facility, the elaboration of the hazardous waste management plan was found to be more difficult, mainly because of the geographical isolation of the mine. So, it was first recommended to replace hazardous raw materials when possible. Moreover, the separation of all the waste streams for possible waste reuse was implemented in the mine. Finally, the most important measure was the beginning of the technical study for using spent oils in the mining facility as raw material for the production of the explosives (used as first step in metals recovery from the rock). For this purpose, and to storage hazardous wastes in the facility, it was recommended that the plant should obtain the respective environmental permissions as a hazardous waste elimination facility.

In the case of sawmill and wood remanufacturing facility, the main conclusion was that a waste management plan should first start with waste separation in origin, for implementing strategies to minimize in plant waste generation. In this sense, oil and solvents use minimization measures were implemented in plant. In addition, separation, recovery and marketing of recyclable wastes like paper and cardboard, plastics and metals were also implemented. Finally, all the identified sub-products (bark, sawdust and shaves) were recovered and burned in the different plant boilers for energy recovery.

The present strategies for all study cases represent the status of the current technological development in Chile regarding hazardous waste management. As already mentioned, the new "Hazardous Waste Management Regulation" has pushed to a more sound management of the generated hazardous wastes all over the country. However, it is expected that the technical requirements of the different management alternatives will be increased in the coming years, aiming for a larger energy and material recovery; in despite of landfilling the generated wastes.

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