processing practices. Water consumption and wastewater characteristics vary widely as it is highly dependent on the type of product being processed, the equipment and processes used, and the water conservation practices employed.

Operations that use water as a transport medium (e.g. wet conveying) tend to generate higher volumes of wastewater and have higher organic loads. Conventional blanching and cooking operations also use significant quantities of water.

3.4.4 Waste Minimization Options

Water recycling is one of the best options to minimize wastewater generation. Simple primary treatment of wash water such as using sedimentation basins and reusing the water for initial product washing may also be useful. Organic loads may be minimized to some extent by minimizing the contact between the water and the product although this has to be balanced with maintaining cleaning standards.

Table 2 summarizes the waste minimization opportunities for Food (fruit and vegetable processing) industries.

3.5 WM techniques for the Foundry Industry

3.5.1 Profile of the Foundry Sector

The Foundry industry is commonly known as the metal forming industry. It finds application in several key areas such as information technology, food production, and telecommunications, nuclear power and world finance. It can be confidently predicted that as the human race continues its progress, whatever new materials are utilized, the casting industry is needed to serve it.

Metal casters are some of the world's first recyclers. For centuries, foundries have been making new metal objects by remelting old ones. In fact, the oldest existing casting is a copper frog made in Mesopotamia and dating back to 3200 BC.

Old and discarded products such as appliances, sewer grates cans, automobiles and water meters are not trash to foundries –they are raw materials. Foundries convert unwanted scrap metal into valuable products such as faucets, engine blocks, golf clubs, aluminum wheels and much more. As different industries started to use metal as a key component in their production, the demand for it also increased. To cater to the enormous demands for these products, different metal-casting techniques have been developed.

3.5.2 Typical Process Description

Metalcasting involves moulding, machining and metal cleaning / stripping.

Table 2. Waste Minimization Opportunities for the Food (Fruit) Processing

Process Stage	Options	Opportunity
Inputs and Inventory	Modify Inputs	Work with suppliers to improve quality (e.g. feedstock/product condition, ripeness, damage, and variety).
	Inventory Management	Reduce input losses (particularly short shelf life fruit and vegetables) by instituting "just-in-time" purchasing.
Ingredient Dispatch / Make-up	Process Improvement	Improve product-conveying systems (counter-current vs. single pass, dry conveying vs. wet conveying).
Product Preparation	Process Control / Improvement	Minimize product contact during the cleaning process.
		Investigate whether all the preparation steps are necessary (e.g. does the product have to be peeled?)
		Optimize batch dump frequency (e.g. brine and caustic that may be reused in processing).
		Investigate best available technology for slicing, cutting, peeling, evaporating and sterilizing etc.
		Install drip trays to catch juice/product on conveyors, preparation and trimming tables.
		Investigate different blanching processes to reduce water usage, increase process speed.
Re-use and Recycling	Reuse	Re-circulate product wash water in non-critical cleaning processes.
		Reuse flume water after settling, sedimentation or other appropriate treatment.
		Regenerate cooking oils either on-site or off-site.
	Recycling	Recover valuable materials from the waste stream (e.g. starch, sugar, citrus oil etc.). Wash organic residues to extract valuable by-products.
		Identify opportunities for solid organic waste materials use (e.g. agricultural land spreading, composting, and etc.).
Waste Treatment and Disposal		Remove excess water from organic solid waste by mechanical means or using waste heat to minimize disposal/transport costs.
Marketing / Product Improvement		Develop new products that allow the use of off-specification material and high-quality trimmings (e.g. jams, cut products, etc.).

Moulding / Casting Process

Casting means forming a metal part by pouring molten metal into a sand mould or metal die. The mould or die is comprised of two halves, that when mated together, forms a cavity into which the molten metal is poured and eventually molded. After the metal hardens, the mould is broken. For a sand mould, the metal is then removed and prepared for finishing operations. The sand mould is remolded and used again. The die mould on the other hand, is separated to remove the solidified metal and is re-used.

The most common alloys used in the industries today are shown in the Table 3.

The following are the different end-users of metal castings.

- Automotive & Light Trucks
- Pipe & Fittings
- Construction, Mining & Oil Field Equipment
- Internal Combustion Engines
- Railroad
- Valves
- Farm Machinery
- Municipal Castings (manhole covers, grates, etc.)
- Pumps and compressors

Table 3. Most Common Alloys Used

Ferrous Metals	Nonferrous Metals
Cast Iron	Cast Aluminum
Gray Iron	Cast Copper Alloy
Ductile Iron	Brass
Malleable Iron	Bronze
Compacted Graphite Iron	Zinc
Cast Steel	Magnesium
Carbon & Low Alloy	Titanium
Corrosion Resistant	Nickel
Heat Resistant	Cobalt
Manganese	Tin

There are several methods currently used to produce a metal casting:

Sand-casting uses loose sand that is packed around a pattern to form a hollow shape into which the molten metal is poured. The metal casting formed in this process is subjected to further finishing operations such as machining and testing.

Shell molding is a variation of sand casting. Coating a hot metal pattern with resin-impregnated sand forms a mould. The heat from the metal melts the resin, which in turn holds the sand together to form a shell. Shell casting allows better control of the shape and size of the metal and produces smoother surface which reduces the cost of finishing.

Die-casting differs from the two preceding methods. The die mould is made of a durable material, usually heat resistant metal that can be used several times. Die mould produces accurate and very smooth metal casting. It is however, limited to small castings and to low melting point metals such as zinc and aluminum alloys. Molten metal is poured into the mould and allowed to solidify. Once, the metal has solidified the die is opened and the metal removed. The die is re-closed to receive more molten metal and start the cycle all over again. The whole process may be controlled automatically and may be run by a machine.

In the **V process** unbounded sand is held in place in the mold by a vacuum. A tightly conforming thin sheet of plastic is applied with vacuum after being heated to cover the pattern. A flask is placed over the plastic coated pattern, and is filled with free-flowing sand. Another sheet of plastic is placed over the top of the sand in the flask and the flask is evacuated. The vacuum "hardens" the sand so the pattern can be withdrawn. The other half of the mold is made the same way. After cores are put in place, the mold is closed and poured while still under vacuum. When the metal has solidified, the vacuum is turned off and the sand runs out freely, releasing the casting. This process produces metal castings with very smooth surface finish.

Casting operation may be considered an environmental friendly operation. The only wastes it produces are the spent moulds made of sand, which can be used to manufacture bricks, concrete and construction backfill.

Machining Process

Machining operation involves various metal cutting processes. It uses cutting tools that travel along the work piece, shearing away the metal ahead of it. Some of the machining operations are: turning, drilling, milling, reaming, threading, broaching, grinding, polishing, planning, cutting and shaping. During cutting operations, metal working fluids are applied to the work piece to facilitate the cutting operation. The different types of fluids that may be used are water, emulsions of soluble oil or paste and oils such as mineral, sulphurized, or chlorinated oil. These metal working fluids, which may be considered hazardous, and should be properly disposed of or recycled -on or –off site.

Metal Cleaning/Stripping

Cleaning and stripping plays an essential part in the whole manufacturing process. In this stage, metal parts are cleaned with solvents. Depending on the proceeding process, the metal is cleaned by either one or a combination of the following media: solvents, alkaline cleanser, acid cleansers, non-chemical abrasive materials and water.

The composition of the waste produced depends entirely on the type of cleaning media used, type of substrate and the type of soil removed (oils, waxes, greases, metallic particles, oxides and etc.).

Metal surface treatment and plating involves the alteration of the metal wok piece's surface properties. These operations are typically done in batches, that is, metals are dipped into and then removed from baths containing various reagents in order to achieve the desired surface condition. There are three basic steps used in this operation: a.) Surface cleaning, b.) Actual modification of the surface, c.) Rinsing or other finishing operations.

Wastes produced in this operation are listed in Table 4.

Surface coatings are used wherever it is desired to provide protection, decoration and/or safety marking to a product or item. Most paint coatings for fabricated metals are solvent based although water based materials are starting to replace it. Wastes produced in this stage are usually paint containers, spent cleaning solutions, paint over spray, spent stripping solutions and equipment cleaning wastes.

Table 4. Various Wastes Generated from Metal Stripping

Waste Description	Process Origin	Composition
Spent process solutions	Plating and chemical conversion	Electroplating bath constituents
Filter sludges	Plating and chemical conversion	Silica, silicides, carbides, ash, plating bath constituents
Quench oils and quench oil tank clean-up wastes	Case hardening	Oils, metal fines, combustion products
Spent salt bath	Carburizing, nitriding, cyaniding	Sodium cyanide and cyanate. Potassium cyanide and cyanate
Waste water treatment sludge	Waste water treatment	Metal hydroxides, sulfides, carbonates
Vent scrubber wastes	Vent scrubbing	Similar to process solution composition
Ion exchange resin reagents	Demineralization of process water	Brine, HCl, NaOH

3.5.3 Environmental Concerns

Metal casting generates solid and liquid wastes and air emissions. Typical solid wastes generated include:

- Spills from pouring operations
- Returns from casting operations
- Rejects from poured castings
- Slag from melting operations
- Sludge from wet dust collectors
- Waste sand from molding operations

Most of these wastes can be recycled or remelted. Others can be properly disposed either as fill materials or sold to interested buyers.

Liquid wastes generated are cooling water from furnace coolers and heat exchangers and drain water from washing operations.

Air emissions include fumes from cupola, induction and oil furnaces; saw dust and planer chips from the patterns shops; dust from the molding; and volatile organic compounds from the cleaning/ finishing operations.

3.5.4 Waste Minimization Options

Setting up a WM program does not require unconventional or expensive technologies. Some of the most effective techniques are simple and inexpensive. Others require significant capital expenditures. However many provide a considerable return on investment. These are summarized in Table 5, followed by brief descriptions.

Table 5. Waste Minimization Options for Foundry

Options	Opportunities
Improved Operating Procedures	Improved personnel practices, housekeeping,, inventory control, waste stream segregation, preventive maintenance
Materials Substitution	Substitution of steel scraps with low lead and cadmium content as raw material;
	Elimination of reactive desulfurization slag
Process Modification and Redesign	Designs that reduce volume of waste, energy and maintenance costs
Treatment Alternatives	Methods that reduce toxicity of waste which can not be totally eliminated
Recycling	Use, reuse and reclamation of scrap steel, by products from the conversion of coal into coke, and foundry sand
Energy Conservation and Pollution Reduction	Reduce demand for energy and reduce wastes for landfills

Improved Operating Procedures

Good operating procedures rely not on changes in technology or materials, but on human adaptability. Small changes in personnel practices, housekeeping, inventory control, waste stream segregation, material handling and scheduling improvements, spill and leak prevention and preventive maintenance can mean big waste reductions. Some examples in the steel industry include:

- Improved production process control.
- Proper management of oils used for machinery maintenance.
- Recycling approaches and compliance record should be of high priority criteria for selection of waste management contractors. Company personnel must carefully monitor the contractor’s waste management methods and operations.

Materials Substitution

Disposing of hazardous materials has become expensive. It makes sense to substitute less hazardous materials whenever possible. Good material choices can also increase opportunities to recycle. Consider the following substitutions:

Use steel scrap with low lead and cadmium content as a raw material, if possible.
Eliminate the generation of reactive desulfurization slag generated in foundry work by using a less hazardous material in place of calcium carbide.

Process Modifications & Redesign

Because of the high costs of end-of-pipe treatment and disposal, source reduction becomes an attractive investment. Greater reductions are possible when metallurgical engineers trained in pollution prevention incorporate waste reduction into process design projects. Designs that reduce the volume of waste generated can also reduce energy consumption, and maintenance costs. For example:

- A new technology uses an induction-heated holding furnace following the electric arc furnace to feed the metal in a pseudoplastic state to multiple continuous casting machines. Advantages of this modification include the elimination of the structural defects that may result from using the traditional approach and better conditions for near-net shaping.
- Switching to induction melting furnaces for gray iron melting can reduce or eliminate the need for air pollution control equipment.
- Replace single-pass wastewater systems with closed-loop systems to minimize chemical usage in wastewater treatment and to reduce water use.

Treatment Alternatives

Alternative treatment methods can reduce the toxicity or volume of certain waste streams, which can not be eliminated. For example:

- In the ductile iron industry, use of thermal destruction of calcium carbide desulfurization slag by rotary kiln; or a chemical reaction between the slag and strong oxidizing agents such as potassium permanganate and hydrogen peroxide, can reduce toxicity.
- Reduce the leaching potential of toxic metals through precipitation, absorption, chemical reduction, or pH control.

Recycling

Recycling is the use, reuse, or reclamation of a waste after it is generated by a particular process. The steel industry recycles extensively by using scrap steel as raw material. By-products created when coal is converted to coke, such as coke oven gas, coal tar, crude or refined light oils, ammonium sulfate, anhydrous ammonia and naphthalene, are also used as raw materials for other industrial processes. Examples of other recycling opportunities include:

- Convert tar-decanter sludge (and other tar-based coke plant wastes) into a fuel that is suitable for open hearth and blast furnaces.

- Recycle or reuse oils and greases. Dewater and recycle mill scale, and recharge slag into the melting furnaces.
- Recover zinc from electric arc furnace dust.
- Recover acids by removing dissolved iron salts from spent acid. For example, employ thermal decomposition for recovery of hydrochloric acid from spent pickle liquor.
- Recover ferric sulfate or ferric chloride from pickle liquor through crystallization.
- Employ the use of a spray roaster, a fluid bed, or a sliding bed to separate hydrochloric acid from iron oxide in spent pickle liquor.
- Use a bipolar membrane/electro dialytic process to separate acid from metal by-products in spent NO_3-HF pickle liquor.
- Recover sulfuric acid using low temperature separation of acid and metal crystals.

One of the major environmental concerns of the foundry is the generation of large volume of wastes sand. Casting processes require large volumes of sand, which are continually used, reconditioned and reused in the foundry. Sand that can no longer be reused in the foundry process can be re-used. Most foundries have installed sand reclamation systems that screen the metal and debris out of the sand so that a good, clean product is available for reuse in a variety of applications and industries.

Recycled Foundry Sand (RFS)

Foundries produce RFS generally in proportion to their overall production volume, although there are different sand-to-metal ratios employed in different casting processes and products.

Most foundries have two sand systems, one feeding the external molding lines and one feeding the internal core lines. After the metal is poured and the part is cooled, green sand is literally shaken off the castings, recovered and reconditioned for continual reuse. Used cores are also captured during this cooling and “shake out” process. These are broken down, crushed and reintroduced into the green sand systems to replace a portion of sand lost in the process. Broken and/or excess cores, or those cores that do not break down, are discarded.

RFS is high quality silica sand with uniform physical characteristics. It is a byproduct of the ferrous and nonferrous metal casting industry, where sand has been used for centuries as a molding material because of its thermal conductivity. In modern foundry practice, sand is typically recycled and reused through many production cycles.

Depending on the projected end use, it may be important to segregate sand streams at the foundry as each stream can have different characteristics. Additionally, some sand is typically unrecoverable during the “shake out” and finishing processes. These sands may be contaminated with metal and/or very large chunks of burned cores (referred to as core “butts”) and will need to undergo some type of segregation, crushing and screening before recycling.

Used sand can be reused for the following purposes:

- Construction Fill
- Road Sub base

- Grouts and Mortars
- Potting and Specialty Soils
- Cement Manufacturing
- Precast Concrete Products
- Highway Barriers
- Pipe Bedding
- Asphalt
- Cemetery Vaults
- Brick and Pavers
- Landfill Daily Cover

Energy Savings and Pollution Reduction

Making castings from recycled metal products saves energy and conserves resources. Since foundries produce castings with recycled content, it reduces the need for raw materials and energy. Processing raw materials places heavy demands on the nation's energy resources. By comparison, it requires 95% less energy to make castings out of recycled metals.

Reprocessing used materials in the foundry industry also has a domino effect by reducing the energy demands for mining, refining and many other metal-related processes. Recycling also reduces pollution risks by keeping materials out of disposal facilities. For instance, reusing steel reduces both water and air pollution and saves water, compared to making new steel from iron ore. According to the U.S. Environmental Protection Agency (EPA), recycling steel, rather than using iron ore reduces air pollution by 86%, water use by 40%, and water pollution by 97% and mining wastes by 97%.

In summary, foundry sand may clear leachate standards. The foundry industry can easily attain ZERO waste. Foundries can treat and recycle all of their wastewater, sand and other refuse, or find beneficial reuses for it, producing no waste to be land filled. Foundry sand can be used to make concrete, cement, block and bricks — all of which are basic construction materials. And foundry sand and other recycled materials are commonly found in roads (asphalt), gardens (mulch), building (blocks), parking lots (concrete) and recreation areas (specialty topsoils).

3.6 WM Techniques for the Chemical Processing Industry

3.6.1 Profile of the Chemical Industry

In the late 19th century, the Philippine Chemical Industry was primarily composed of small-scale companies engaged in rudimentary production of chemical products. These products are classified as such only because they involved some chemical processes.

Impacts to the environment brought about by the operation of these industries are inevitable. Depending on the type of chemical industry, its repercussions to the environment may also vary from one industry to the other. Effects to the environment of the production and use of chemical may not be as apparent. It may be in the form of the depletion of important natural resources, physical disruption, energy use and release of hazardous substances into the environment through extraction of raw materials and the impacts of transporting the raw materials and processed chemicals or products. There are, therefore, two challenges. One is to reduce the amount of energy and raw materials consumed in the production and use of chemicals, and the second is to reduce emissions.

3.6.2 Waste Minimization Options

Waste minimization options may change depending on the type of industry. In general, however, cleaner production principles can be applied. This can be done by reducing material inputs, re-engineering processes to reuse by-products, improving management practices, and employing substitute toxic chemicals. It is also possible to actually get below regulatory thresholds just by reducing pollutant releases through aggressive WM and pollution prevention policies.

WM in the inorganic chemicals industry is somewhat restricted to the less costly options, such as minor process modifications, operational changes, raw material substitutions, and recycling.

WM in the chemical industry is process specific. As such it is difficult to generalize about the relative merits of different WM strategies. The age and size of the facility, and the type and number of its processes will determine the most effective WM strategy. General WM techniques found to be effective at inorganic chemicals facilities are provided in Table 6 and described below.

Substitute raw materials

The substitution or elimination of some of the raw materials used in the manufacturing of inorganic chemicals can result in substantial waste reductions and cost savings. Since some impurities in the feed stream can be a major contributor to waste generation, one of the most common substitutions is to use a higher purity feedstock. This can be accomplished either by working in collaboration with suppliers to get a higher quality feed or by installing purification equipment. Raw materials can also be substituted with less toxic and less water soluble materials to reduce water contamination, and with less volatile materials to reduce fugitive emissions. Sometimes raw materials that end up as waste can be eliminated altogether by modifying the process and improving control.

Improve reactor efficiencies

Since chemical products are primarily created inside the process reactor, it can be the primary source for waste (off-spec) materials. One of the most important parameters dictating the reactor efficiency is the quality of mixing. A number of techniques can be used to improve mixing, such as installing baffles in the reactor, a higher rpm motor for the agitator, a different mixing blade design, multiple impellers, and pump re-circulation. The method used to introduce feed to the reactor can also have an effect on the quality of mixing. A feed distributor can be added to equalize residence time through the reactor, and feed streams can be added at a point in time closer to the ideal reactant concentration. This will avoid secondary reactions that form unwanted by-products.

Improve catalyst

The catalyst plays a critical role in the effectiveness of chemical conversion in the reactor. Alternative chemical make-ups and physical characteristics can lead to substantial improvements in the

Table 6. Waste Minimization Opportunities for Chemical Production

Options	Opportunities
Raw materials substitution	Collaborate with suppliers or install purification equipment to get a higher quality feed
	Substitute with less toxic, less water soluble and less volatile materials to reduce water contamination and / or fugitive emissions
Improve Reactor Efficiencies	Use different techniques to improve quality of mixing in the process reactor
Improve catalyst	Use alternative chemicals to improve effectiveness and life of a catalyst, or use different catalysts to eliminate by products
Optimize Processes	Explore use of computer controlled systems and other process optimization techniques
Reduce heat exchanger wastes and inefficiencies	Use techniques to reduce heat exchanger tube wall temperature without reducing the overall heat transferred
Improve wastewater treatment and recycling	Modernize wastewater treatment technologies or alter the manufacturing process with a view to selling concentrated waste streams as a product
	Reuse wastewater stream
Prevent leaks and spills	Follow preventive maintenance and leak detection programs
Improve inventory management and storage	Prevent materials wastage
	Reduce materials use and reduce contamination and dispersal

effectiveness and life of a catalyst. Different catalysts can also eliminate by-product formation. Noble metal catalysts can replace heavy metal catalysts to eliminate wastewater contaminated with heavy metals. Using a more active form can reduce the consumption of catalysts. Obtaining the catalyst in the active form can eliminate emissions and effluents generated during catalyst activation.

Optimize processes

Process changes that optimize reactions and raw materials use can reduce waste generation and releases. Using computer controlled systems, which analyze the process continuously and respond more quickly and accurately than manual control systems may prove to be effective. These systems are often capable of automatic startups, shutdowns, and product change over which can bring the process to stable conditions quickly, minimizing the generation of off-spec wastes. Other process optimization techniques include equalizing the reactor and storage tank vent lines during batch filling to minimize vent gas losses; sequencing the addition of reactants and reagents to optimize yields and lower emissions; and optimizing sequences to minimize washing operations and cross-contamination of subsequent batches.

Reduce heat exchanger wastes and inefficiencies

Heat exchangers are often the source of significant off-spec product wastes generated by overheating the product closest to the tube walls. The best way to reduce off-spec product from overheating is by reducing the heat exchanger tube wall temperature. This can be accomplished through a number of techniques which do not reduce the overall heat transferred such as reducing the tube wall temperature and increasing the effective surface area of the heat exchanger; using staged heating by first heating with waste heat, then low pressure steam, followed by superheated high pressure steam; monitoring and preventing fouling of the heat exchanger tubes so that lower temperature heat sources can be used; using non-corroding tubes which will foul less quickly than tubes that corrode.

Improve wastewater treatment and recycling

A large portion of the inorganic chemical industry's pollutants leaves the facilities as wastewater or wastewater treatment system sludge. Improved treatment and minimization of wastewater are effective pollution prevention opportunities that often do not require significant changes to the industrial processes. Modern wastewater treatment technologies such as ion exchange, electrolytic cells, reverse osmosis, and improved distillation, evaporation, and dewatering can often be added to existing treatment systems. Wastewater streams containing acids or metals can be concentrated enough to be sold commercially as a product by slightly altering the manufacturing process, adding processing steps, and segregating wastewater streams. Furthermore, many wastewater streams can be reused within the same or different processes, significantly reducing discharges to the wastewater treatment system.

To illustrate, an inorganic chemicals plant making photochemistry solution generates wastewater containing silver. Electrolytic cells were installed that recovered 98 percent of the silver and an evaporator was added that concentrated the remaining liquid for disposal resulting in a 90 percent reduction in waste volume.

Prevent leaks and spills

The elimination of sources of leaks and spills can be a very cost effective pollution prevention opportunity. Leaks and spills can be prevented by installing seamless pumps and other "leakless" components, maintaining a preventative maintenance program, and maintaining a leak detection program.

Improve inventory management and storage

Good inventory management can reduce the generation of wastes by preventing materials from exceeding their shelf life or from being left over or not needed, and reducing the likelihood of accidental releases of stored material. Designating a materials storage area, limiting traffic through the area, and giving one person the responsibility to maintain and distribute materials can reduce materials use, and reduce contamination and dispersal of materials.