Ingeo™ Foam Sheet Extrusion Processing Guide

This information is intended for use only as a guide for the manufacture of an amorphous Ingeo foam sheet ranging between 40 - 200 mils (1.0 – 5.0 mm). Cell size will also be a function of type and level of nucleating agent and blowing agent but NatureWorks LLC has achieved cell sizes in the range of 250 – 500 micron with typical nucleant loadings. Typically foams can be made with closed cell count between 20 and 95% and is heavily dependent upon the melt temperature. Because the foam is amorphous, any trays thermoformed from this resin will be suitable for use up to 120°F (49°C). Exceeding this temperature will result in product deformation. Because extrusion of Ingeo sheet foam is complex, an experimental approach may be required to achieve optimal results.

1.0 Safety and Handling Precautions

All safety precautions normally followed in the handling and processing of melted thermoplastics should be followed for Ingeo.

As with most thermoplastics, melt processing and the variability of those conditions may result in minor decomposition. Lactide, a non-hazardous gaseous irritant, is a minor by-product of Ingeo melt processing. Appropriate air testing should be completed to ensure an acceptable Threshold Limit Value (TLV, based on a Time Weighted Average of 8 hours) of less than 5 mg/m3 is maintained. The use of process area point source remediation measures such as monomer fume hoods or exhausts near the die are typically recommended.

Molten Ingeo has a lower viscosity and sticks more readily to cloth, metal, brass and wood compared to other molten thermoplastics. Be prepared for this when cleaning die faces, collecting molten patties and emptying purge containers. Unlike polyolefins, a molten web of Ingeo will not release as cleanly from a gloved hand so use caution when grabbing any stream or patty of Ingeo.

At ambient temperatures, Ingeo is considered non-hazardous according to DOT (US Department of Transportation) shipping regulations. When handling Ingeo at room temperature avoid direct skin and eye contact along with conditions that promote dust formation. For further information, consult the appropriate MSDS for the Ingeo grade being processed.

As with any melted thermoplastic waste, melted Ingeo waste should be allowed to cool before being placed into any waste container to minimize fire risks.

Foam extrusion has an additional concern due the use of blowing agents. Often times these blowing agents are flammable hydrocarbons that pose a significant risk if not handled properly. NatureWorks LLC requires that the use of flammable blowing agents with Ingeo is restricted to facilities that have been designed to deal with these risks. Adequate ventilation, anti-static controls, appropriate electrical connections and proper operating procedures should be in place and in good operating condition before any attempt is made to use these agents with Ingeo resins.

2.0 Pellet Storage and Blending Recommendation

Ingeo should be stored in an environment designed to minimize moisture uptake. Product should also be stored in a cool place at temperatures below 140°F (60°C).

Product that is delivered in cartons or super sacks should be kept sealed until ready for loading into the blending and/or drying system. Bulk resin that is stored in closed silos and hoppers for extended periods (more than 6 hrs) should be kept purged with dry air or nitrogen to minimize moisture gain. In the case of outside storage, if the product is supplied in boxes or other non-bulk containers, the unopened container should be brought into the extrusion production area and allowed to equilibrate for a minimum of 24 hours before opening to prevent excessive condensation.

3.0 Resin Selection and Properties

Ingeo 8052D is the recommended Ingeo grade for foam sheet production of amorphous sheet foam. Typical properties of 8052D are shown in the table below.

Typical Ingeo 8052D Properties

Resin Property	Nominal Value
RV	3.3 – 3.5
Melt Processing Point (primary extruder), °F (°C)	400 – 440 (200 – 225)
Glass Transition Temperature, °F (°C)	125 – 135 (52 – 57)

4.0 Materials of Construction

All metal parts in the extrusion process that are subjected to stagnant flow areas with molten polymer should be constructed of stainless steel to minimize corrosion. This includes filter assemblies and some transfer lines. Furthermore, Ingeo should not be left in the extruder, polymer filter, polymer transfer lines, dies or any other part of the extrusion system at Ingeo melt temperatures or higher for extended periods. Below is a guideline for the recommended types of steel that should be used in the extrusion system.

Part	Steel Type
Transfer lines and filters	SUS440C
Die	Hard Chrome plated tool steel

5.0 Drying

Ingeo can be successfully dried using most standard drying systems. Recommended conditions are provided for standard desiccant based column dryers. For other drying system designs, additional information can be provided upon request.

To prevent equipment corrosion, it is not recommended to dry or store hot Ingeo in carbon steel vessels (see Section 2.0).

In-line drying is essential for Ingeo. It is recommended that 8052D should be dried to a maximum of 50 ppm of moisture as measured by a Karl Fischer method for maximum retention of molecular weight and physical properties. Material is supplied in foil-lined containers dried to less than 400 PPM as measured by NatureWorks LLC's internal method. The resin should not be exposed to atmospheric conditions after drying. Keep the package sealed until ready to use and promptly dry and reseal any unused material. The drying table below can be used to estimate the drying time needed for Ingeo. Air or nitrogen based desiccant drying systems can be used at the recommended temperatures. Typical Ingeo drying conditions are shown in the table below.

Typical Ingeo Raw Material Drying Conditions

Drying Parameter	Typical Settings
Residence Time (hours)	3
Air Temperature °F (ºC)	165 (74)
Air Dew Point °F (ºC)	- 40 (-40)
Air Flow Rate, CFM/lb resin (m^3 / hr - kg resin)	> 0.5 (1.85)

Typical desiccant dryer regeneration temperatures exceed the melt point of Ingeo. To prevent issues with pellet bridging, sticking or melting, the drying system should be verified to ensure temperature control is adequate during operation as well as during regeneration cycles since valve leakage is common in many systems. Installation of a water cooled heat exchanger may be necessary to prevent the drying air temperature from exceeding the recommended set point.

6.0 Melt Foam Extrusion

There are several components to achieving success when extruding Ingeo into a foam sheet.

1. Equipment preparation and cleaning through purging
2. Resin selection
3. Branching additive selection
4. Nucleating agents
5. Blowing agent
6. Other additive
7. Melt extrusion
8. Die design
9. Foam stabilization

6.1 Ingeo Purging Procedure

Prior to introducing Ingeo into any melt processing system, the system should be properly cleaned and purged to prevent any polymer cross contamination. Insure that the feeding & blending equipment is thoroughly cleaned & free from dust and contamination and all metal magnets have been wiped clean. Insure that all hang-up areas such as elbows transitions and slide gates have all previously run dust and granules completely removed. The purging procedures below are recommended for optimal removal of other polymers.

Following PP or PS in your system

1. Introduce a high melt flow PP (5 - 8 MFR) or PS (6 –10) first at normal PP or PS conditions, then reduce temperatures to recommended Ingeo temperatures. Purge for at least 7x average residence time. Let system empty as much as possible.
2. Turn off extruder and completely clean all hoppers, elbow, slide gates, dryers, hopper loaders bins, hopper loader filters and material conveying lines of residual PP or PS. Load Ingeo into material handling system.
3. Transition to the purge Ingeo and purge following for a minimum 7x the average residence times. The screen pack should be changed when it becomes obvious that primarily Ingeo is exiting the die. Do not reduce temperatures in the secondary extruder or die until it is obvious that all remaining PP or PS has been removed from the system.
4. At the completion of the run, purge all Ingeo from the extrusion system, using a moderate to low melt index PP or PS, immediately after completion of the production run.

Notes:

1. It is critical that all drying and conveying/receiving systems be free of all PS or PP and is vacuumed to ensure that there is no remaining polymer dust, before adding Ingeo.
2. The brand of PP used for purging is unimportant, as long as it does not thermally cross-link.

6.2 Resin Selection

The most appropriate grade for the production of an amorphous Ingeo foam is Ingeo 8052D. This resin is a medium molecular weight grade.

6.3 Branching Additive Selection

By itself, Ingeo 8052D does not have sufficient melt strength to allow the formation of a low density closed cell foam and therefore, the use of an appropriate branching agent to improve the melt strength is necessary. NatureWorks LLC has investigated a number of branching agents and found that one is far superior in terms of ease of use, branching effectiveness and food contact approval. The recommended formulation is shown in the table below:

Additive	%	Supplier
Joncryl® 4368C	0.7	BASF Corporation
Mistron® Vapor-R (or equivalent)	0.25 – 0.50	Luzenac America
Ingeo 8052D	98.8 – 99.05	NatureWorks LLC

The use of masterbatches of the additives is recommended to improve the accuracy of dosing and aid in the dispersion. One commercial source of Joncryl® masterbatch is CESA Extend OMAN 698493 sold by Clariant Additives Masterbatches as a 30% concentrate in a Ingeo base carrier. To achieve a final concentration of 0.7% would mean an addition rate of 2.3% of the 30% masterbatch. Polyvel, Inc sells a 20% concentrate of talc masterbatch in a Ingeo carrier that would be 1.25 – 2.5% to achieve the desired level of talc in the final foam.

Since this particular branching agent reacts with the polymer backbone, it is critical that there is sufficient reaction time at the reaction temperature to ensure a complete reaction and that the shear rate and melt temperature in the primary screw are low enough to prevent degradation of molecular weight as the output (screw speed) is increased. As a general rule of thumb, the melt temperature of the resin in the primary screw should remain below 440°F to ensure polymer integrity

6.4 Nucleating Agent Selection

Foam extrusion requires the use of additives to achieve a quality low-density product. Primarily, some type of nucleating agent should be used to control cell size and population. Nucleating agents are typically used as a masterbatch. It is critical that any masterbatch is produced with Ingeo as the carrier resin. NatureWorks LLC recommends 8052D as the carrier resin for any additive masterbatch system but other grades potentially could be used. While there are numerous types of foam nucleating agents, NatureWorks LLC has had good success with talc commonly used in the polystyrene foam industry. The product is Mistron Vapor R produced by Luzenac America. The product specifications are listed in the table below. Any type of talc with similar particle size should behave similarly as the Luzenac product.

Property of Mistron Vapor R (LA51)	Specification
Median Particle Size	2.2 +/- 6 micron (Test Method LSTM – 02)
Hegman Fineness	5.5 – 6.25 (Test Method LSTM-17)
GE Brightness	> 85 with 86 Target (Test Method LSTM – 14)

Sometimes chemical nucleating agents are used in the production of foam products. While this is possible also in Ingeo, there is no clear benefit to using these agents except for specialized applications. It should be noted that many of the chemical nucleating agents will release water in addition to gases during thermal activation. These agents are not recommended for Ingeo as water will promote molecular weight loss during Ingeo extrusion.

6.5 Blowing Agent

Many of the conventional blowing agents used for producing expanded polystyrene can also be used for blowing Ingeo. A low density foam with high closed cell count has been produced with butane, pentane, R152a and R142b blowing agents. In general, the hydrocarbons are slightly less soluble in Ingeo than the R152a and R142b and therefore will not plasticize the gel as readily. This may result in slightly higher motor loads and head pressures but in most cases the differences are insignificant.

6.6 Other Additives

In addition to nucleating agents, there are other additives that could be used in Ingeo foam such as colors, slip agents or anti-static agents. In all cases, these additives should be compatible with Ingeo and consistent with the other foam end use properties. The additives should also be used as Ingeo masterbatches to prevent the introduction of other polymers into the foam.

The list of suppliers of Ingeo color concentrates and additives continues to grow and a preliminary list is included in the table below. However, NatureWorks LLC encourages you to contact you present supplier if not listed below to see if they have added Ingeo concentrates to their product portfolio.

Color Concentrate Supplier	Telephone Number
Clariant Additive Masterbatches	540-665-1865
Plastic Color Corporation	708-868-3800
Sukano Polymers Corporation	864-486-1478
PolyOne	866-765-9663
Polyvel, Inc	609-567-0080

6.7 Melt Extrusion

The successful extrusion of Ingeo foam requires a) a complete reaction of the foam branching agent which is dependent upon melt temperature and residence time and b) sufficient cooling of the melt to assure a high quality foam. To accurately monitor the melt temperature at both the crossover and die exit, it is highly recommended that an exposed junction, variable depth thermocouple be installed at these two locations. Only an exposed junction variable depth thermocouple will give an accurate indication of the melt temperature without significant influence of the surrounding steel temperatures. In this guide, all melt temperatures referenced are measured with this type of device. Other types will give temperatures that are somewhere between the actual melt temperature and the surrounding steel temperature.

Screw Design

Conventional screw designs used for the extrusion of PS foam on tandem extruders are generally unacceptable for the extrusion of amorphous Ingeo foam. In the primary screw, the design of the gas injection zone is such that the pressure is generally too high when running Ingeo and often will exceed the limit of the gas system pressure resulting in a lower than desired flow rate of blowing agent. The secondary screw does not have the cooling capabilities or low enough shear input to allow for sufficient cooling of the Ingeo gel. The TurboScrew™ technology developed and licensed by Plastics Engineering Associates Licensing, Inc. (contact information in the Appendix) has been shown to have the ability to process Ingeo on commercial equipment at commercially viable extrusion rates. All the conditions below were developed using TurboScrews on both primary and secondary extruders. While the possibility of other screw designs does exist, it should be noted that several extrusion trials conducted on various commercial lines fitted with conventional polystyrene foam screw designs have resulted in the inability to adequately cool the melt in the secondary extruder. In all cases, the resulting melt temperature is too high because the energy added to the system in the form of shear heat from the screw rotation, exceeds the ability to remove heat from the barrel walls.

As noted in previous sections, the melt temperature at the end of the primary screw is a critical process parameter as this will determine the rate of branching agent reaction. While generally the temperature should be between 420 – 460°F, other temperatures may be required depending upon the design of the crossover piping. Please refer to Section 6.3 for more information on properly balancing the melt temperature and residence time.

The power requirements for Ingeo are also different than polystyrene because of the high pellet bed COF and the different rheology. The table below lists the expected specific energy requirements for both the primary and secondary extruder when running Ingeo at the recommended conditions.

	Specific Energy Input (HP-hr/lb)
Primary Extruder	0.28 – 0.31
Secondary Extruder	0.12 – 0.14

Typical Ingeo Extrusion Conditions

Primary Extruder	**Temperature Setting, ºF (ºC)**
Feed throat cooling	60 - 70 (15 – 20)
Screw cooling	60 - 70 (15 – 20)
Zone 1	170 (75)
Zone 2	315 (155)
Zone 3	420 (215)
Zone 4	420 (215)
Zone 5	420 (215)
Zone 6	420 (215)
Screen changer	420 (215)
Transition	420 (215)
Desired final crossover temperature	430 – 450 (220 – 235)
Cooling Extruder	
Melt Seal Zone 1	200 (95)
Melt Seal Zone 2	325 (165)
Zone 1	260 – 400 (125 - 200)
Zone 2	220 - 260 (105 -125)
Zone 3	200 – 240 (93 - 115)
Zone 4	190 – 230 (88 – 110)
Zone 5	180 – 220 (83 - 105)
Die	
Die Body	280 - 300 (138 - 150)
Die Lips	290 – 310 (143 - 155)
Die Spider	280 – 300 (138 - 150)
Desired melt temperature	285 – 290 (140 – 143)
Mandrel temperature	
	60 – 80 (15 – 25)

As with most foam extrusion processes, the secret to making Ingeo foam lies in the cooling that can be achieved in the secondary extruder. As the melt temperature drops after start up, the extrudate will move from a low melt strength gel with evidence of bubbles but no significant expansion. As the temperature reaches approximately 310 F (155 C) the gel will start to expand and at that time, it should be possible to stretch the web over the mandrel to the winder. At this point, the foam will be largely an open cell foam. Further reduction of the melt temperature will result in improved expansion as the melt strength continues to improve and the cells remain intact.

6.8 Die Design

As noted above, Ingeo does not shear thin to the degree that PS does and therefore special consideration should be given to the die, lip set and mandrel used for Ingeo foam extrusion. In general, a low-pressure die should be used with Ingeo in order to stay close to the extruder head pressure right up to the die lips. The majority of the die pressure drop should occur right at the lips in order to prevent pre-foaming which would result in a loss of foam quality. The die gap should be adjustable to produce a variety of foam thicknesses on a single die. In addition, the die lip set diameter and the mandrel diameter should be such that a 4:1 or greater blow up ratio is achieved in the foam. The die gap will vary according to the gauge of foam, output and die design but for a typical low pressure die producing an 8.0 basis weight (nominal 140-mil thick) foam, a starting die gap of 28-mils is recommended.

6.9 Foam Stabilization

Ingeo has a glass transition temperature of 140°F (55°C). As a result, the extruded foam must be below this temperature before slitting and exiting the mandrel. Because this glass transition temperature (Tg) is 40°C less than the Tg of PS, the cooling conditions used for PS are generally insufficient to stabilize Ingeo. NatureWorks LLC suggests several design modifications. First, a chilled coolant should be used on the mandrel. Mandrel temperatures as low as 40°F (5°C).are sometimes necessary. Second, an auxiliary cooling ring should be used to force air over the outer surface of the foam as it travels over the mandrel. This is in addition to the air ring typically used at the die to control the foam surface quality. Finally, a mandrel extension may be necessary to give the foam more residence time prior to slitting. The best way to monitor foam stabilization is to measure the foam sheet width after slitting. The width of the foam should be equal to or slightly greater than the circumference of the mandrel. If it is less, then the foam is shrinking after slitting and more cooling capabilities should be added.

7.0 Web Handling and Slitting

The toughness of Ingeo is slightly greater than PS. The web is easily slit at the mandrel with a rotary cutting knife. A simple razor knife will work for Ingeo foams but is more sensitive to the foam quality. Ingeo foam, like most foam webs, can generate a high degree of static charge as it is moving over process equipment. Anti-static solutions and ionizers can be used to eliminate the static charge and prevent the risk of explosion, especially when using flammable blowing agents.

8.0 Thermoforming

8.1 Sheet Storage Recommendations

Ingeo foam sheet made from Ingeo 8052D resin should be stored in an environment designed to minimize moisture uptake, and in a cool place at temperatures below 40°C (104oF). In environments above 40°C and above 50% RH, the sheet is susceptible to molecular weight breakdown and loss of physical strength over extended periods of time.

8.2 Thermoforming and Trimming

Ingeo 8052D foam can be manufactured on conventional thermoforming equipment typically used for Polystyrene foam with minor process changes. In general, oven temperatures will be lower than polystyrene and mold temperatures will be cooler for best performance. Trim tooling may need to be modified if gaps are large and incomplete cutting results. This can be accomplished by reducing the gap between the trim plates until complete cutting occurs. Other process parameters typically used for PS foam forming generally are acceptable for Ingeo foam thermoforming.

In thermoforming Ingeo foam, it is important to heat the entire sheet to a temperature between 185 and 220F. Typical oven residence times of 10 to 30 seconds provides sufficient time to heat the sheet above 185F for good thermoforming and acceptance of mold detail without thermally damaging the sheet surface retaining a smooth glossy appearance. Oven residence times beyond 30 seconds may result on sheet sag. The amount of available residence time varies from machine to machine and depends on three factors; 1) oven length 2) index length 3) cycle time.
To determine if the current set-up on a machine will be adequate, divide oven length (O) by index length (I) and multiply by cycle time (C). If O/I*C is between 10 and 30 seconds, the current set-up will be a good starting point. During heater setup, sheet surface temperature should be taken with an infrared (IR) thermometer at the center of the sheet as it indexes over the mold. Adjust the oven to achieve a sheet surface temperature of approximately 200 F.

Mold temperatures should be kept at a minimum for best performance. A mold temperature of 15C has been found to work best for most parts at standard production rates however mold temperatures up to 25C can be used depending on part thickness and mold residence time. In general if warped parts are obtained, cooling time should be increased or mold temperature decreased.

Line	Irwin 50-160
Heater Length	160 inches
Heater Setpoint	300°F
Sheet Temp	175°F
CPM	20
Oven Res Time	12.5 secs
Mold Temp	75°F

9.0 Scrap and Skeleton Reprocessing

While Ingeo can be successfully reprocessed at typical addition ratios used in the foam industry; there are differences. These differences arise from the fact that Ingeo, like PET, is subject to hydrolytic degradation if processed in the presence of water (See Section 5.0). Therefore, care must be taken that the moisture level of the Ingeo is less than 250 ppm before any melt process step is taken.

The reprocessing of foam Ingeo scrap involves the following unit operations

1. Grinding
2. Densification with or without drying
3. Drying for subsequent extrusion into foam

9.1 Grinding

Ingeo regrind is not compatible with regrind from any other sheet product. It is necessary to both wipe and water wash clean the grinding equipment and transfer lines or to have dedicated systems for Ingeo. Ingeo must be about 40°C (104°F) or less to grind efficiently. Some grinding systems require additional cooling to efficiently grind Ingeo.

9.2 Densification

The ground fluff needs to be densified for subsequent blending with virgin resin and feeding into the primary extruder. Ingeo fluff can be densified in several different ways, all which are commonly used in the Ingeo industry. It is important to note that due to the hydrolytic nature of Ingeo, any processing step where the temperature of the Ingeo exceeds 230°F (110°C) for more than 20 seconds may require a preliminary drying step if the moisture content of the fluff exceeds 400 ppm.
Consult your NatureWorks LLC technical representative when designing and operating any Ingeo melt processing operation as they have the experience and analytical tools to ensure that densification is achieved with the lowest possible amount of polymer degradation.

9.3 Drying

Prior to extruding the reclaimed foam scrap into foam, the material must be dried as the virgin resin. This can be accomplished in a dedicated drier or the densified material can be blended with the virgin material and dried together.

10.0 Appendix

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Safety and Handling Considerations

Safety Data Sheets (SDS) for Ingeo biopolymers are available from NatureWorks. SDS's are provided to help customers satisfy their own handling, safety, and disposal needs, and those that may be required by locally applicable health and safety regulations. SDS's are updated regularly; therefore, please request and review the most current SDS's before handling or using any product.

The following comments apply only to Ingeo biopolymers; additives and processing aids used in fabrication and other materials used in finishing steps have their own safe-use profile and must be investigated separately.

Hazards and Handling Precautions

Ingeo biopolymers have a very low degree of toxicity and, under normal conditions of use, should pose no unusual problems from incidental ingestion or eye and skin contact. However, caution is advised when handling, storing, using, or disposing of these resins, and good housekeeping and controlling of dusts are necessary for safe handling of product. Pellets or beads may present a slipping hazard.

No other precautions other than clean, body-covering clothing should be needed for handling Ingeo biopolymers. Use gloves with insulation for thermal protection when exposure to the melt is localized. Workers should be protected from the possibility of contact with molten resin during fabrication.

Handling and fabrication of resins can result in the generation of vapors and dusts that may cause irritation to eyes and the upper respiratory tract. In dusty atmospheres, use an approved dust respirator.

Good general ventilation of the polymer processing area is recommended. At temperatures exceeding the polymer melt temperature (typically 175ºC), polymer can release fumes, which may contain fragments of the polymer, creating a potential to irritate eyes and mucous membranes. Good general ventilation should be sufficient for most conditions. Local exhaust ventilation is recommended for melt operations. Use safety glasses (or goggles) to prevent exposure to particles, which could cause mechanical injury to the eye. If vapor exposure causes eye discomfort, improve localized fume exhausting methods or use a full-face respirator.

The primary thermal decomposition product of PLA is acetaldehyde, a material also produced during the thermal degradation of PET. Thermal decomposition products also include carbon monoxide and hexanal, all of which exist as gases at normal room conditions. These species are highly flammable, easily ignited by spark or flame, and can also auto ignite. For polyesters such as PLA, thermal decomposition producing flammable vapors containing acetaldehyde and carbon monoxide can occur in almost any process equipment maintaining PLA at high temperature over longer residence times than typically experienced in extruders, fiber spinning lines, injection molding machines, accumulators, pipe lines and adapters. As a rough guideline based upon some practical experience, significant decomposition of PLA will occur if polymer residues are held at temperatures above the melting point for prolonged periods, e.g., in excess of 24 hours at 175°C, although this will vary significantly with temperature.

Combustibility

Ingeo biopolymers will burn. Clear to white smoke is produced when product burns. Toxic fumes are released under conditions of incomplete combustion. Do not permit dust to accumulate. Dust layers can be ignited by spontaneous combustion or other ignition sources. When suspended in air, dust can pose an explosion hazard. Firefighters should wear positive-pressure, self-contained breathing apparatuses and full protective equipment. Water or water fog is the preferred extinguishing medium. Foam, alcohol-resistant foam, carbon dioxide or dry chemicals may also be used. Soak thoroughly with water to cool and prevent re-ignition.

Disposal

DO NOT DUMP INTO ANY SEWERS, ON THE GROUND, OR INTO ANY BODY OF WATER. For unused or uncontaminated material, the preferred option is to recycle into the process otherwise, send to an incinerator or other thermal destruction device. For used or contaminated material, the disposal options remain the same, although additional evaluation is required. Disposal must be in compliance with Federal, State/Provincial, and local laws and regulations.

Environmental Concerns

Generally speaking, lost pellets, while undesirable, are benign in terms of their physical environmental impact, but if ingested by wildlife, they may mechanically cause adverse effects. Spills should be minimized, and they should be cleaned up when they happen. Plastics should not be discarded into the environment.

Product Stewardship

NatureWorks has a fundamental duty to all those that use our products, and for the environment in which we live. This duty is the basis for our Product Stewardship philosophy, by which we assess the health and

environmental information on our products and their intended use, and then take appropriate steps to protect the environment and the health of our employees and the public.

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