ADMINISTRATIVE INFORMATION

Project Name:	*Low Temperature Pasteurizer*	**Faculty Guide:**	*TBD*
Project Number:	*P12401*	**Industry Guide:**	*Sarah Brownell*
Project Track:	*Energy and Sustainable Systems*	**Project Customer:**	*Haitians*
Project Family:	*Design for Developing Nations*	**Project Sponsor:**	*RIT*
Parent Roadmap:	*n/a*	**Project Budget:**	*TBD*
Planning Term:	*Spring 2012*		
Start Term:	*Fall 2012*		
End Term:	*TBD*		

PROJECT OVERVIEW

In the 1950's Haitian agriculture employed nearly 80 percent of the workforce, was responsible for over half of the country's GDP, and accounted for over 90 percent of the country's exports. Since then Haiti's soils have been tormented by over-cultivation, extreme deforestation, soil erosion, droughts, flooding and natural disasters. Now agriculture, along with forestry and fishing, only account for about a quarter of Haiti's exports. Only 60 percent of the Haitian workforce is now employed by the agricultural industry (oxfam.com).

The largest impact do to the degradation of the agricultural industry in Haiti is experienced in rural villages where farming is a livelihood In addition, there is no proper plumbing in rural Haiti, and proper sanitation management is unheard of. Human waste, along with regular waste (i.e. table scraps and organic material) goes unused or even leaches into local water supply.

The objective of this project is to compost human waste and other organic waste to use as fertilizer and enrich the agricultural soils. The primary concern to using fecal matter as compost is the pathogens contained within the feces that promote deadly diseases. Pathogens, related disease, pathogenic survival, and pathogen indicators can be referenced in the short study, "Pathogen Study", which is attached to this document.

The most convenient solution is to pasteurize (or cook) the waste to kill off the pathogens. There are two processes to eliminating the pathogens. The first is to pasteurize the human waste prior to composting it with other organic waste. Doing so also eliminates effective microbial bacteria that promotes decomposition and would slow down the composting process. The second solution is to pasteurize the human and organic waste after it has been composted together. The only concern with this solution is to keep the user (or handler) out of direct contact with the compost so as not to come in direct contact with the existing pathogens.

The target end users will be residences of rural villages, and therefore there are many constraints do to the limited resources. There is no electricity in the rural villages. Also, Haiti's rural residences are by large impoverished and their economic means are limited; therefore any solution must be affordable. The constraints are listed on the next page.

References are listed at the bottom of this document as well as on the "Pathogen Study" document.

CUSTOMER NEEDS & CONSTRAINTS:

The customer needs and constraints were based off of interviews with Sarah Brownell (sabeie@rit.edu) and Alex Martinez (student). Each customer needs and constraints has an individually ranked and ranked by importance (9 – Very Important, 3 – Important, 1 – Moderately Important).

CN1	Contain Pathogens	25	9
CN2	Make end product free of pathogens	24	9
CN3	Cost <$100	22	9
CN4	Safe Human Interface	21	9
CN5	Environmetal Resistance	20	9
CN6	Easily Repaired	19	3
CN7	Easy to add/stir/remove material	16	3
CN8	Easy to access	14	3
CN9	Use Local Materials	13	3
CN10	Easy to Relocate	13	3
CN11	Compost complete in set time	11	1
CN12	Consistant source of fertilizer	8	1
CN13	Minimize compost time	7	1
CN14	Minimize smell	5	1

****LOW TEMPERATURE PASTEURIZER – CONSTRAINT****

You have been assigned the “Low Temperature Pasteurizer” that will be characterized as a pasteurizer that does not exceed 50°C.

In reference to Figure 7.7 of the Pathogen Study (and of the Humanure Handbook), pathogens heated to 50°C or below take more than one day to be eliminated.

Constraint	**Derived from Customer Need**	**Relative Importance**	**Description**
1	CN3	9	Keep total cost of manufacturing and shipping product less than $100
2	CN3, CN6, CN9	3	Product made from locally availlable materials
3	CN6, CN10	3	No electric tools must be required to assemble, disassemble or repair the product
4	CN10	3	The assemble time of the product should be less than 6 hours

ENGINEERING SPECIFICATIONS:

The engineering specifications were derived from the customer needs and reviewed by the customer. Notice that the customer constraints are not listed as they are standalone items.

Engineering Specification	Derived from Customer Need	Relative Importance	Description	Measure of Performance	Engineering Units	Marginal Value	Ideal Value	Source
ES1	CN2	9	Provide heat to waste using solar energy in order to elimintate pathogens to safe level	Temperature, Time	°F, hours	Refer to Tables 7.2, 7.7, 7.14, and 7.15 of the Pathogen Study		Humanure Handbook
ES2	CN4	9	Vent combustive gases in order to prevent explosions	Amount of methane inside chamber	ppm	50,000	Less than 30,000	http://www.ccohs.ca/oshanswers/chemicals/chem_profiles/methane/health_met.html
ES3	CN1	9	Contain pathogens, do not allow unsafe leakage of unteated wastes	Is there leakage?	Binary (Yes/No)	No	No	
ES4	CN4	9	Temperature of the access door (or handle of the access door)	Temperature	°F	120°F	Less than 100 °F	http://engineering.union.edu/SeniorProjects/2004.ME/arthurk2/Background.htm
ES5	CN5	9	The product must be able to withstand an outdoor environment	Does rain water leak into the chamber	Binary (Yes/No)			
ES6	CN5	3	The product must be able to withstand an outdoor environment	Does the product withstand outdoor wind	mph	20 mph	25 mph	http://haitipassivecooling.tumblr.com/
ES7	CN7, CN8	3	Customer must be able to easily add, stir (optional) and remove waste	Time to add, stir and remove material	minutes	15 minutes	less than 5 minutes	
ES8	CN10	3	Volume of product	Volume	Liters		1L per person per day*	http://bend.org.au/uploads/media/CompostingLoos.pdf
ES9	CN11, CN12, CN13	1	Waste must be turned to useable fertilizer**	Is fertilizer made?	Binary (Yes/No)	Yes	Yes	
ES10	CN14	9	Minimize Smell	Does the product smell bad?	Survey	80% think its ok	90% think its ok	
ES11	CN2	9	Does the entire sample of human waste contain safe pathogen levels?	Test for pathogen level		See attached table. Refer to Humanure Handbook for more details		Humanure Handbook Table 7.2

* Please note that the total volume of the pasteurizer would be dependent on how quickly the design kills the pathogens, i.e. a slower pasteurizer would require a larger volume.
** The pasteurizer does not have to compost the waste. The composting can be done before or after the pasteurization process. (Eg. Reintroduce good microbes after pasteurization)

<u>VOICE OF THE ENGINEER to VOICE OF THE CUSTOMER</u>:

Engineering specifications are directly mapped to customer needs. Most customer needs are directly mapped to constraints.

Needs and Specs	ES1	ES2	ES3	ES4	ES5	ES6	ES7	ES8	ES9
CN1			9						
CN2	9								
CN3*									
CN4		9		9					
CN5					9				
CN6*									
CN7						3			
CN8						3			
CN9*									
CN10*							3		
CN11								1	
CN12								1	
CN13								1	
CN14									1
* Customer need is addressed in constraints									

<u>REFERENCES</u>:

"Agriculture in Haiti." *Wikipedia*. Wikimedia Foundation, 18 May 2012. Web. 21 May 2012. <http://en.wikipedia.org/wiki/Agriculture_in_Haiti>.

"Economy of Haiti." *Wikipedia*. Wikimedia Foundation, 19 May 2012. Web. 21 May 2012. <http://en.wikipedia.org/wiki/Economy_of_Haiti>.

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Design Project Management
R12401 – Design for Developing Nations
Pasteurizer
PATHOGEN STUDY

Pathogens are made up of:

1. Viruses
2. Bacteria
3. Protozoa
4. Worms (Helminths)

(Bacteroides, Salmonella, Shigella, Yersinia, Campylobacter, Aeromonas, Candida, E. coli O157, Cryptosporidium, Entamoeba histolytica)

"Drying toilets are increasingly popular in the developing world where arid climates can dry excrement fast and where water is scarce. Many of these systems rely solely on dehydration to desiccate the feces. This matter is then put out on fields. Urines is diverted and drained into the nearby soil. (Urine can make an excellent fertilizer, but it is rarely collected from these systems.) Often caustic lime or wood ash is added to control odors, but these additives are a double-edged sword: They do aid in odor control, but they can also inhibit or stop the natural biological decomposition process. The result is dried, unstable feces and toilet paper." (http://oikos.com/library/compostingtoilet/pathogens.html)

Killing Pathogens:

"The only sewage digestion process producing a guaranteed pathogen-free sludge is batch thermophilic digestion in which all of the sludge is maintained at 50°C (122°F) for 13 days." (Humanure Handbook)

"Complete pathogen destruction is guaranteed by arriving at a temperature of 62°C (143.6°F) for one hour, 50°C (122°F) for one day, 46°C (114.8°F) for one week, or 43°C (109.4°F) for one month. It appears that no excreted pathogen can survive a temperature of 65°C (149°F) for more than a few minutes." (Humanure Handbook)

Pathogenic Indicators

"Indicator pathogens are pathogens whose detection in soil or water serves as evidence that fecal contamination exists. The astute reader will have noticed that many of the pathogenic worms listed in Table 7.6 are not found in the United States. Of those that are, the Ascaris lumbricoides (roundworm) is the most persistent, and can serve as an indicator for the presence of pathogenic helminths in the environment." (Humanure Handbook).

"Ascaris eggs develop at temperatures between 15.50C (59.90°F) and 350C (950 F), but the eggs disintegrate at temperatures above 380C (100.40° F).28 The temperatures generated during thermophilic composting can easily exceed levels necessary to destroy roundworm eggs." (Humanure Handbook).

"One way to determine if the compost you're using is contaminated with viable roundworm eggs is to have a stool analysis done at a local hospital. If your compost is contaminated and you're using the compost to grow your own food, then there will be a chance that you've contaminated yourself. A stool analysis will reveal whether that is the case or not. Such an analysis is relatively inexpensive." (Humanure Handbook).

There are indicators other than roundworm eggs that can be used to determine contamination of water, soil or compost. Indicator bacteria include fecal coliforms, which reproduce in the intestinal systems of warm blooded animals (see Table 7.7). If one wants to test a water supply for fecal contamination, then one looks for fecal coliforms, usually Escherichia coli. E. coli is one of the most abundant intestinal bacteria in humans; over 200 specific types exist. Although some of them can cause disease, most are harmless.29 The absence of E. coli in water indicates that the water is free from fecal contamination." (Humanure Handbook).

"Water tests often determine the level of total coliforms in the water, reported as the number of coliforms per 100 ml. Such a test measures all species of the coliform group and is not limited to species originating in warm-blooded animals. Since some coliform species come from the soil, the results of this test are not always indicative of fecal contamination in a stream analysis. However, this test can be used for ground water supplies, as no coliforms should be present in ground water unless it has been contaminated by a warmblooded animal." (Humanure Handbook).

"Bacterial analyses of drinking water supplies are routinely provided for a small fee by agricultural supply firms, water treatment companies or private labs." (Humanure Handbook).

Table 7.1

POTENTIAL PATHOGENS IN URINE

Healthy urine on its way out of the human body may contain up to 1,000 bacteria, of several types, per milliliter. More than 100,000 bacteria of a single type per milliliter signals a urinary tract infection. Infected individuals will pass pathogens in the urine that may include:

Bacteria	**Disease**
Salmonella typhi	Typhoid
Salmonella paratyphi	Paratyphoid fever
Leptospira	Leptospirosis
Yersinia	Yersiniosis
Escherichia coli	Diarrhea
Worms	**Disease**
Schistosoma haematobium	schistosomiasis

Source: Feachem et al., 1980; and Franceys, et al. 1992; and Lewis, Ricki. (1992). *FDA Consumer*, September 1992. p. 41.

Table 7.2

MINIMAL INFECTIVE DOSES
For Some Pathogens and Parasites

Pathogen	**Minimal Infective Dose**
Ascaris	1-10 eggs
Cryptosporidium	10 cysts
Entamoeba coli	10 cysts
Escherichia coli	1,000,000-100,000,000
Giardia lamblia	10-100 cysts
Hepatitis A virus	1-10 PFU
Salmonella spp	10,000-10,000,000
Shigella spp	10-100
Streptococcus fecalis	10,000,000,000
Vibrio cholerae	1,000

Pathogens have various degrees of *virulence*, which is their potential for causing disease in humans. The minimal infective dose is the number of organisms needed to establish infection.

Source: Bitton, Gabriel. (1994). Wastewater Microbiology. New York: Wiley-Liss, Inc., p. 77-78. and *Biocycle*. September 1998. p. 62.

Table 7.4

POTENTIAL BACTERIAL PATHOGENS IN FECES

Bacteria	Disease	Symptomless Carrier?
Campylobacter	Diarrhea	yes
E. coli	Diarrhea	yes
Salmonella typhi	Typhoid fever	yes
Salmonella paratyphi	Paratyphoid fever	yes
Other *Salmonellae*	Food poisoning	yes
Shigella	Dysentery	yes
Vibrio cholerae	Cholera	yes
Other *Vibrios*	Diarrhea	yes
Yersinia	Yersiniosis	yes

Source: Feachem et al., 1980

Figure 7.7

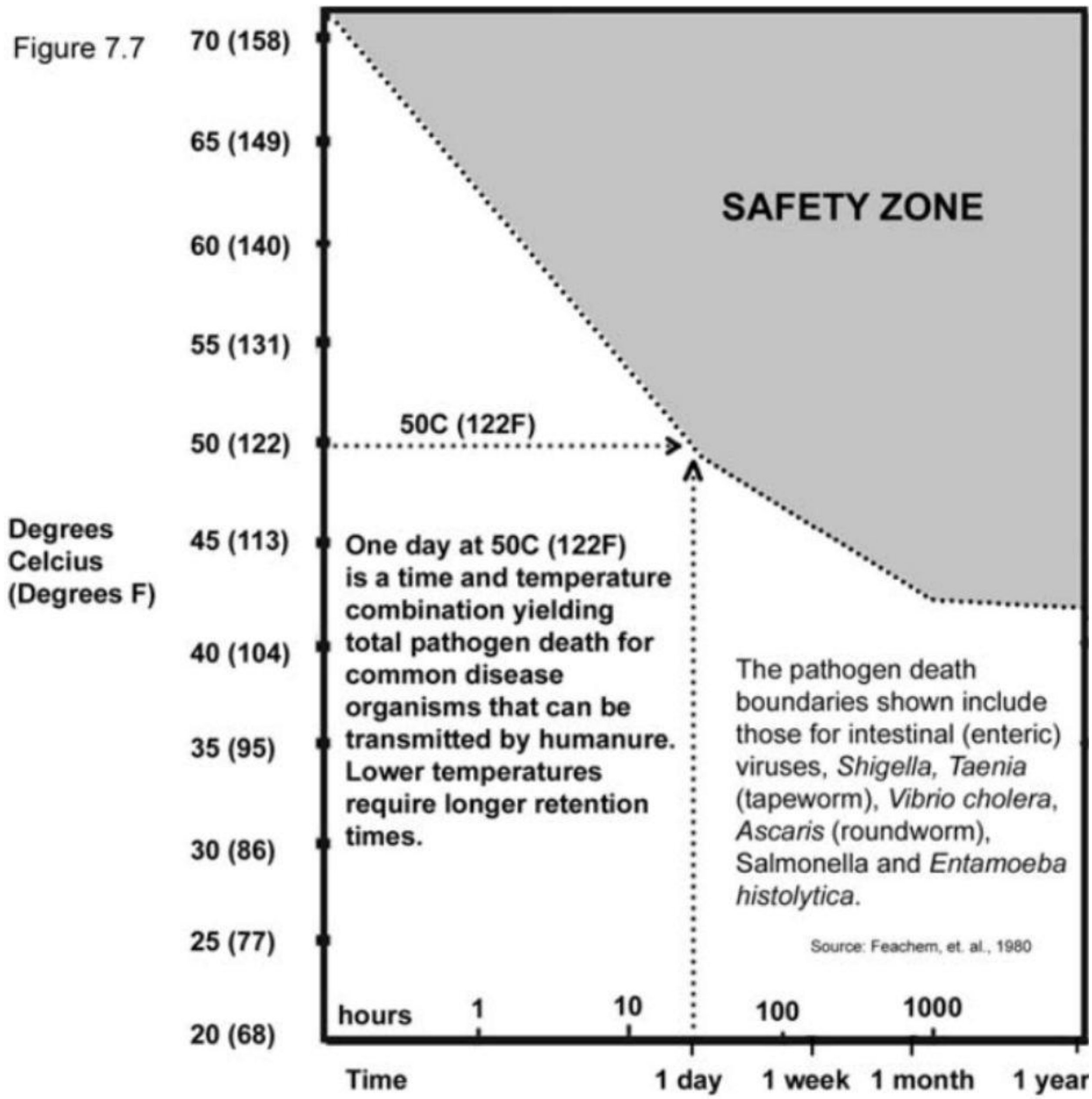
70 (158)
65 (149)
60 (140)
55 (131)
50 (122)
45 (113)
40 (104)
35 (95)
30 (86)
25 (77)
20 (68)
Degrees Celcius (Degrees F)
SAFETY ZONE
50C (122F)
One day at 50C (122F) is a time and temperature combination yielding total pathogen death for common disease organisms that can be transmitted by humanure. Lower temperatures require longer retention times.
The pathogen death boundaries shown include those for intestinal (enteric) viruses, Shigella, Taenia (tapeworm), Vibrio cholera, Ascaris (roundworm), Salmonella and Entamoeba histolytica.
Source: Feachem, et. al., 1980
hours
1
10
100
1000
Time
1 day
1 week
1 month
1 year

Table 7.12

SURVIVAL TIME OF SOME PATHOGENIC WORMS IN SOIL

Soil	Moisture	Temp. (°C)	Survival
HOOKWORM LARVAE			
Sand	?	room temp.	< 4 months
Soil	?	open shade, Sumatra	< 6 months
Soil	Moist	Dense shade	9-11 weeks
		Mod. shade	6-7.5 weeks
		Sunlight	5-10 days
Soil	Water covered	varied	10-43 days
Soil	Moist	0	< 1 week
		16	14-17.5 weeks
		27	9-11 weeks
		35	< 3 weeks
		40	< 1 week
HOOKWORM OVA (EGGS)			
Heated soil with night soil	water covered	15-27	9% after 2wks
Unheated soil with night soil	water covered	15-27	3% after 2wks
ROUNDWORM OVA			
Sandy, shaded		25-36	31% dead after 54 d.
Sandy, sun		24-38	99% dead after 15 d.
Loam, shade		25-36	3.5% dead after 21 d.
Loam, sun		24-38	4% dead after 21 d.
Clay, shade		25-36	2% dead after 21 d.
Clay, sun		24-38	12% dead after 21 d.
Humus, shade		25-36	1.5% dead after 22 d.
Clay, shade		22-35	more than 90 d.
Sandy, shade		22-35	less than 90 d.
Sandy, sun		22-35	less than 90 d.
Soil irrigated w/sewage		?	less than 2.5 yrs.
Soil		?	2 years

Source: Feachem et al., 1980; d.=days; <=less than

Table 7.13

PARASITIC WORM EGG DEATH

Eggs	Temp.(⁰C)	Survival
Schistosome	53.5	1 minute
Hookworm	55.0	1 minute
Roundworm	-30.0	24 hours
Roundworm	0.0	4 years
Roundworm	55.0	10 minutes
Roundworm	60.0	5 seconds

Source: Compost, Fertilizer, and Biogas Production from Human and Farm Wastes in the People's Republic of China, (1978), M. G. McGarry and J. Stainforth, editors, International Development Research Center, Ottawa, Canada. p. 43.

Table 7.14

PATHOGEN SURVIVAL BY COMPOSTING OR SOIL APPLICATION

Pathogen	Soil Application	Unheated Anaerobic Digestion	Composting Toilet (Three mo. min. retention time)	Thermophilic Composting
Enteric viruses	May survive 5 mo	Over 3 mo.	Probably elim.	Killed rapidly at 60C
Salmonellae	3 mo. to 1 yr.	Several wks.	Few may surv.	Dead in 20 hrs. at 60C
Shigellae	Up to 3 mo.	A few days	Prob. elim.	Killed in 1 hr. at 55C or in 10 days at 40C
E. coli	Several mo.	Several wks.	Prob. elim.	Killed rapidly above 60C
Cholera vibrio	1 wk. or less	1 or 2 wks.	Prob. elim.	Killed rapidly above 55C
Leptospires	Up to 15 days	2 days or less	Eliminated	Killed in 10 min. at 55C
Entamoeba histolytica cysts	1 wk. or less	3 wks or less	Eliminated	Killed in 5 min. at 50C or 1 day at 40° C
Hookworm eggs	20 weeks	Will survive	May survive	Killed in 5 min. at 50C or 1 hr. at 45C
Roundworm (*Ascaris*) eggs	Several yrs.	Many mo.	Survive well	Killed in 2 hrs. at 55C, 20 hrs. at 50C, 200 hrs. at 45°C
Schistosome eggs	One mo.	One mo.	Eliminated	Killed in 1 hr. at 50°C
Taenia eggs	Over 1 year	A few mo.	May survive	Killed in 10 min. at 59°C, over 4 hrs. at 45°C

Source: Feachem et al., 1980

Table 7.15
THERMAL DEATH POINTS FOR COMMON PARASITES AND PATHOGENS

PATHOGEN	THERMAL DEATH
Ascaris lumbricoides eggs	Within 1 hour at temps over 50^{0}C
Brucella abortus or *B. suis*	Within 1 hour at 55^{0}C
Corynebacterium diptheriae	Within 45 minutes at 55^{0}C
Entamoeba histolytica cysts	Within a few minutes at 45^{0}C
Escherichia coli	One hr at 55^{0}C or 15-20 min. at 60^{0}C
Micrococcus pyogenes var. *aureus*	Within 10 minutes at 50^{0}C
Mycobacterium tuberculosis var. *hominis*	Within 15 to 20 minutes at 66^{0}C
Necator americanus	Within 50 minutes at 45^{0}C
Salmonella spp.	Within 1 hr at 55C; 15-20 min. at 60^{0}C
Salmonella typhosa	No growth past 46C; death in 30 min. 55C
Shigella spp.	Within one hour at 55^{0}C
Streptococcus pyogenes	Within 10 minutes at 54^{0}C
Taenia saginata	Within a few minutes at 55^{0}C
Trichinella spiralis larvae	Quickly killed at 55^{0}C

Source: Gotaas, Harold B. (1956). Composting - Sanitary Disposal and Reclamation of Organic Wastes . p.81. World Health Organization, Monograph Series Number 31. Geneva.

Table 2. Survival of Animal Fecal Pathogens in the Environment

Material	Temp	Duration of Survival					
		Giardia	Crypto-sporidium	Salmonella	Campylo-bacter	Yersinia entercoliticia	E. coli O157:H7
Reference		21-23	24-25	26-28	29-31	30,37	32-36
Water	frozen	< 1 day	> 1 year	>6 mos	2-8 weeks	> 1yr	>300 days
	cold (5C)	11 wks	> 1 year	>6 mos	12 days	>1 yr	>300 days
	warm (30C)	2 wks	10 wks	>6 mos	4 days	10 days	84 days
Soil	frozen	< 1 day	> 1 yr	>12 wks	2-8 weeks	>1yr	>300 days
	cold (5C)	7 wks	8 wks	12 - 28 wks	2 weeks	> 1yr	100 days
	warm (30C)	2 wks	4 wks	4 wks	1 week	10 days	2 days
Cattle Feces	Frozen	< 1 day	> 1 yr	>6 mos	2-8 weeks	>1yr	>100 days
	Cold (5C)	1 wk	8 wks	12-28wks	1-3 week	30-100 days	>100 days
	Warm (30C)	1 wk	4 wks	4 weeks	1 week	10-30 days	10 days
Slurry		1 yr	>1 yr	13-75 days	>112 days	12-28 days	10-100 days
Compost		2 wks	4 wks	7- 14 days	7 days	7 days	7 days
Dry Surfaces		1 day	1 day	1- 7 days	1 day	1 day	1 day

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"Agriculture in Haiti." *Wikipedia*. Wikimedia Foundation, 18 May 2012. Web. 21 May 2012. <http://en.wikipedia.org/wiki/Agriculture_in_Haiti>.

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Project	ME	ISE	EE	CE	ChE	BioE	ID	Other	Total	BRIEF Mission Statement
R12401 Pasteurizer (Low Temp)	2	1				1			4	The pasteurizer functions at low temperatures (40^{o}C - 50^{o}C).

Position	**Responsibility**
Many team members will play multi-role responsibilities in the project. In many ways each team member will play each role throughout the entire research, design and development process. Understand your own skills and the skills of your teammates to properly assign team member roles. Also, understand that being the team leader does not mean that you are the facilitator, hence they are listed seperately. Mind that giving one person all of the responsibility of moving the team's design forward will put unecessary stress upon that memeber, and will also hinder the rate at which the team progresses. Share the responsibilities of initiative so that if one team member is feeling overwhelmed the other team members can step up and push the team forward.	
Team Leader	The team leader guides the team in a productive direction. In most cases the team leader has the authority of assigning tasks, overseeing that the tasks are done, and coordinates the workflow. Recommended skills for the team leader are: detail oriented, well organized, widespread knowledge and understanding of engineering applications, public speaking skills.
Structural Engineer	The structural engineer is responsible for developing and designing any structural aspects of the design. The structural engineer should be able to conduct structural analysis (either analytical or FEA). The structural engineer is also responsible for the test plan for the structural aspects of the design (the plan in which to test that the design meets the customer's needs and constraints).
Interface Engineer (Everyone)	This is everyone's responsibility. The interface engineer is responsible for the feasability of the design. The interface engineer is also responsible for cooperating with the other team engineers to design and develop concepts. Also, the interface engineer is responsible for assisting the industrial engineer in the ergonomics and interface between the design and its intended user.
Thermal Engineer	The thermal engineer is responsible for developing the thermodynamic design aspects of the system. The thermal engineer should be able to conduct thermodynamic and heat transfer analysis (either analytically or FEA). The thermal engineer should work hand-in-hand with the sanitation engineer to achieve the customer's needs. The structural engineer is also responsible for the test plan for the thermodynamic and heat transfer aspects of the design (the plan in which to test that the design meets the customer's needs and constraints).
Sanitation Engineer	The sanitation engineer's primary responsibility is to understand the specifications the design must meet to maintain a system that is biologically safe for users. The projects referenced above deal with human fecal matter which contain deadly pathogens. The biological engineer should work hand-in-hand with the thermal engineer to make sure that the specifications and metrics are met in the design process.
Facilitator	The facilitator is responsible for leading meeting discussions, and customer contacts. The facilitator is also responsible for distributing meeting minutes. If necessary the facilitator may assign a scribe to record the meeting minutes. The facilitator recommended skills are: detail oriented, articulate, organized, ability to lead and direct conversation, public speaking skills, writing skills.