A Thesis Entitled

Physical and Chemical Modifications of Free Radical Scavengers to Reduce their Radioprotective Potentials for Bacterial Agents

by

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ENTITLED

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BE ACCEPTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR

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An Abstract of

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Annually, an estimated 1.2 million allografts are transplanted in the United States for repair or reconstruction of skeletal defects caused by disease, illness, or injury. Sterilization of these allografts must be performed to prevent disease transmission and reduce the inherent risk of infection. Currently, there is *no single* accepted sterilization technique in the bone and tissue banking industry. Gamma irradiation is the most popular and the safest form of allograft sterilization. However, to attain that level of sterility assurance, the biochemical and biomechanical integrity of the allograft is compromised, which is a serious concern since bone allografts are used in load bearing applications.

Damage to allografts results in the radiolysis of water molecules during gamma irradiation. The water molecules bound to the tissue are essentially split into highly reactive, damaging free radical molecules. These free radicals cleave the collagen molecules in bone allograft tissues. One method to control the formation of these free radicals is to add a free radical scavenger to the bone allograft before gamma irradiation sterilization. However, while the free radical scavenger is protecting the collagen, is there the unintended consequence that the free radical scavenger is also protecting the pathogenetic organisms that should be eradicated? It was hypothesized that small, positively charged, globularly shaped free radical scavengers will protect bacteria more efficiently because the scavenger will be able to penetrate the intracellular space of the cell and thus scavenger for the free radicals that should be killing the bacteria.

To test this hypothesis, viability tests were preformed with *E. coli*. Free radical scavengers were selected based on their charge, size, and shape. Solutions of these scavengers were added to *E. coli* suspended in media and incubated at time points of 0, 10, 20, and 40 hours and then subsequently irradiated to a dose of 500Gy. Results showed that positively charged scavengers protected *E. coli* from the harmful effects of irradiation, p<0.05. Results also indicated that a globular shaped scavenger protects *E. coli*, p<0.05. Additionally, a medium sized molecular weight molecule protected the *E. coli*, however, it may be possible that this protection was based more on chemical specificity than actual size of the molecule.

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The global conclusion of this study is: the addition of a scavenger has proven to alleviate biochemical and biomechanical stress to a bone allograft. However, selection of the proper scavenger is essential. From the results of this study, it would be advantageous to select a scavenger with a molecular weight greater than 250Da, but smaller than 350Da to penetrate the fabric of bone, additionally, to select a scavenger that is linear in shape and has an overall net positive charge. Allograft tissues gamma irradiated in the presence of such a scavenger could be treated with excess doses of irradiation for an elevated level of sterility assurance without worry of biochemical and biomechanical degradation.

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Chapter One Introduction

An allograft is human tissue which is removed from a cadaver and implanted into another person. In 2003, an estimated 1.2 million bone allograft procedures were performed in the United States, up from an estimated 800,000 procedures in 2000 [1]. Bone allograft transplants are preformed for repair or reconstruction of skeletal defects caused by disease, illness, or injury. Bone allograft popularity has been increasing because of their availability and biocompatibility. However, the risk of infection and disease transmission is an eminent risk; therefore terminal sterilization must be performed.

As with any surgical procedure, the risk of disease transmission and infection are inescapable. Traditionally, bone allograft procedures have not carried any additional trepidation due to detailed patient and serological screening. However, a few recent isolated cases have spawned a new look into the safety of allograft processing and handling. As of March 11, 2002, the Center for Disease Control (CDC) has received 26

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reports of bacterial infections associated with musculoskeletal tissue allografts [2]. Thirteen of the 26 patients were infected with a *Clostridium* strain bacterium [2]. In 11 of the 13 cases, additional evidence implicated the allograft itself as the source of the infection [2]. In November 2001, one fatal case came out of Minnesota where a 23-year-old man underwent reconstructive knee surgery using a fresh femoral condyle allograft. A few days after surgery, the patient developed pain in the knee that rapidly progressed to shock; the patient died the following day [3]. A near-fatal case came out of Illinois, where a 17-year-old man underwent reconstructive knee surgery receiving a meniscus and fresh femoral condyle. The next day, the patient developed a fever which did not respond to the first-round of antibiotics. Eight days after surgery, he was admitted to the hospital with a fever of 103.5°F. The patient received strong antibiotics and the fever subsided; the patient is recovering [2]. In each case, all allografts were processed aseptically but did not undergo terminal sterilization.

Bone Allograft Sterilization Overview

There is no current single standard bone allograft tissue processing technique used by tissue banks. Many techniques have been developed and are used by various allograft tissue processing centers around the country. All methods performed must be prepared, validated and in written protocol form to comply with regulations designed to prevent infections disease transmission or cross-contamination during tissue processing [4]. A few of the most popular sterilization techniques are outlined in Table 1.01.

	Aseptic Processing	Ethylene Oxide	Gamma Irradiation	Chemical Treatment
Kills Bacteria	No	\checkmark	\checkmark	\checkmark
Kills Fungi	No	\checkmark	\checkmark	\checkmark
Kills Spores	No	\checkmark	\checkmark	\checkmark
Kills Enveloped / Non- enveloped Viruses	No	No	Dose Dependent	No
Removes Blood and Lipids	Surface Only	No	No	Surface Only
Preserves Strength	\checkmark	\checkmark	Decreases – Dose Dependent	\checkmark
Preserves Biocompatibility	\checkmark	dose dependent	\checkmark	\checkmark
Penetrates into Tissue	Surface only	Thickness dependent	Full penetration	Surface Only

Table 1.01 Comparison of current processing methods for allograft tissue sterilization [4].

A handful companies have been started on the technology of chemical treatment sterilization. Regeneration Technologies, Inc. of Alachua, Florida has developed the patented BioCleanseTM tissue sterilization process that operates on the basis of chemical sterilants and pressure/vacuum treatments to remove blood, lipids, and marrow [5]. NovaSterilis of Lansing, New York has developed the Nova2200 sterilization chamber that operates using supercritical carbon dioxide [6]. Clearant, Inc. of Los Angeles, California has developed the patented Clearant Process® that utilizes a combination of gamma-irradiation and chemical treatments to attain sterile assurance while maintaining mechanical integrity [7]. Each of these companies is in their infancy and their technologies safety and reliance has a limited track record.

Ethylene oxide and gamma irradiation are the two classic sterilization methods. Both are proven methods of eliminating bacteria, viruses, and spores. However, ethylene oxide gas deposits residuals that cannot be fully evacuated from the tissues. These residuals cause an inflammatory response to host tissue making this method unsuitable for allograft tissues [8]. Gamma irradiation is the prime choice because of its wellestablished sterility assurance and it is the only method that penetrates the full thickness of an allograft. However, gamma irradiation will degrade the mechanical properties of bone allograft tissues in a dose dependent manner [9, 10]. Degradation of bone allograft tissues is a serious concern since bone allografts are used in load bearing applications [11].

Sterilization of Bone Allografts by Gamma Irradiation

Gamma irradiation offers superior sterility assurance over any of the competing techniques. For that purpose, many groups have been focused on developing techniques to alleviate the biomechanical damage to bone allograft tissue caused by gamma irradiation sterilization. There is a way to harness the destructive powers of gamma irradiation while maintaining sterility assurance. First, an investigation to how gamma irradiation causes damage to allograft tissues is required.

Gamma irradiation is a highly energetic wave (Figure 1.01) of photons produced from the radioactive decay of cesium-137, cobalt-60, technetium-99m, or americium-241 [12, 13]. Gamma photons are the most energetic photons in the electromagnetic spectrum, traveling at the speed of light; yet, have no mass and no electrical charge [13]. During radioactive decay, a neutron transforms to a proton and a beta particle. The nucleus ejects the beta particle; however, the nucleus still has too much energy and ejects the photon (gamma radiation) to become more stable [13].

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Figure 1.01 Electromagnetic wave spectrum [14].

Sterilization with gamma irradiation occurs when a pathogenetic organism is exposed to gamma rays. Bacteria can be rendered nonviable at a gamma radiation dose of approximately 1.5 – 4.5kGy, bacterial spores require approximately 10 – 45kGy, and viruses require a dose greater than 30kGy [15, 16]. The gamma rays destroy crucial intracellular structures at the molecular level, specifically causing irreversible damage to DNA, rendering the pathogen nonviable. This method works fine for sterilizing metallic surgical equipment, the gamma rays pass directly through the equipment without impairing the performance of the tool. However, when a bone allograft is exposed to gamma irradiation, the gamma photons penetrate the tissue and cause molecular damage compromising the biomechanical integrity of the tissue. The damage induced (by gamma irradiation) to bone allograft tissue occurs because of the inherent tightly bound water within the tissue. When the energy of the gamma photons act upon the water molecules the water molecules becomes ionized; essentially an electron is removed and what is left is an extremely reactive hydroxyl free radical with a lifetime on the order of 10^{-9} to 10^{-11} seconds [15, 17]. The oxidation effects of the ionized water molecules (free radicals) with collagen cause the depolymerization of the triple helix and the impaired ability of the triple helices to assemble into fibrils [15, 18].

This inability of the collagen molecules to reassemble into their native triple helix form after sustaining damage is what weakens the overall biomechanical integrity of the bone allograft. It has been shown that post-yield (plastic deformation) properties are impaired by sterilization while elastic modulus is largely unaffected[15, 19, 20]. Burstein et al. has shown that the elastic deformation of bone is governed by the mineral, while the plastic deformation of bone is governed by the elastic behavior of the collagen matrix [15, 21]. Therefore, it is understood that gamma irradiation impairs the overall integrity of the allograft tissue by deterioration of the collagen structure via a free radical attack [15]. For the purposes of this study, any mention of a free radical will be assumed to be the hydroxyl free radical unless otherwise noted.

One attempt to control the formation of free radicals from water molecules is to simply remove the water. However, there is no technique that can remove all traces of molecular water from allograft tissues. Several studies have been conducted that included lyophilizing the allograft tissue and then irradiating the tissue while it is frozen [22, 23]. The idea being that most of the water was removed by lyophilization and the remaining water, which is frozen, is immobilized from forming free radicals. The results of these attempts showed that mechanical burden was somewhat lessened, but not to an acceptable level [23].

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Free Radical Scavenger

Another method to protect the collagen of allograft tissues from the free radical attack of ionized water would be to capture the free radicals before they have a chance to react with the collagen (Figure 1.02). These agents that are capable of capturing free radicals are known as free radical scavengers (FRS). In biological terms, any agent that is capable of scavenging for free radicals is known as an antioxidant. The human body naturally creates antioxidants to combat the oxidative stress created by the natural processes of cellular metabolism.

Work by Belaney et al. [15] has shown that cortical bone irradiated in the presence of the free radical scavenger thiourea has superior biochemical and biomechanical properties than cortical bone irradiated without the presence of such a scavenger. However, recent work has shown that thiourea is a possible carcinogen, which would not make it an ideal candidate. Therefore, it is necessary to identify potential biocompatible free radical scavengers; ideally those that are naturally occurring in the body or dietary intake.



Figure 1.02 Free radical scavenger proposed mechanism [15].

One potential advantage of the free radical scavenger would be that bone allograft tissues could be irradiated at a much greater dose for greater sterility assurance. Since the collagen composition of the bone would be protected by the FRS, there is the potential to apply a dose of 50kGy or greater, which would safely deactivate the most radio-resistant spores and viruses.

Problem Statement and Hypotheses

In addition to the FRS thiourea being a potential carcinogen, previous work has not addressed another very serious issue. Since the free radical scavenger is protecting the collagen molecules from free radical attack, is there the unintended consequence that the free radical scavenger is protecting the pathogenetic organisms that should be eradicated?

To investigate this problem, bacterial cultures will be treated with various free radical scavengers and subsequently gamma irradiated. The free radical scavengers will be analyzed based on their charge, size, and shape. Viability will be assessed to determine the bacteria log-reduction. It is hypothesized that free radical scavengers that can penetrate the cell membrane will protect the bacteria from gamma irradiation, resulting in a low log-reduction. Scavengers that are positively charged will be attracted to the negatively charged bacteria and have an easier chance of penetrating the bacteria and protecting it from gamma irradiation. Further, scavengers that are small in size will penetrate bacteria easier than large sized scavengers. Scavengers that are linear or planar.

Chapter Two

Experimental Methods and Materials

The purpose of this study was to identify biocompatible free radical scavengers. Additionally, to determine if the selected free radical scavengers protect microbial organisms when exposed to gamma irradiation.

It is widely known that DNA is an easy target for radical attack because the nucleic bases that compose DNA are excellent antioxidants (free radical scavengers), Table 2.01. Thus, it can be assumed that DNA can be more easily damaged than collagen under free radical attack. Therefore, to allow the desired damage to bacterial DNA, the selected free radical scavenger should not penetrate the cellular membrane of a bacterium and enter the intracellular space to protect that DNA.

Compound	Abbreviation	Rate Constant (M ⁻¹ s ⁻¹)
Ascorbic Acid	AA	7.2×10^9
L-Cysteine	LC	$7.9 \ge 10^9$
D-Cysteine	DC	7.9 x 10 ⁹
N-Acetyl-L-Cysteine	NAC	7.9 x 10 ⁹
L-Cysteine Ethyl Ester	LCEE	7.9 x 10 ⁹
L-Cysteine Methyl Ester	LCME	7.9 x 10 ⁹
Uracil	U	$3.1 \ge 10^9$
Epigallocatechin Gallate	EGCG	$4.1 \ge 10^9$
Trehalose	Т	2.7×10^9
Glutathione	G	$8.8 \ge 10^9$
Thiourea	Th	$4.7 \ge 10^9$
Tryptophan	Trp	$8.5 \ge 10^9$
Trp-Trp-Trp	TTT	>8.5 x 10 ⁹
Adenine		3.0×10^9
Cytosine		2.9×10^9
Guanine		$1.0 \ge 10^{10}$
Thymine		3.1×10^9

Table 2.01 Typical second-order rate constants for reactions of free radicals scavengers with the hydroxyl radical [24].

It is known that scavengers with comparable affinities for the hydroxyl free radical will exhibit differing radioprotective effects. For example, glycerol and cysteamine are both potent free radical scavengers; however, glycerol can provide protection to *Salmonella* whereas cysteamine cannot [25-27]. This difference is the important implication that the permeation of a scavenger through the bacterial wall differs. Only those which can permeate the wall will be able to elicit protection to pathogens.

The permeability of a scavenger is a consequence of the diffusibility (kinetics) and solubility (thermodynamics). Diffusibility and solubility depend on the physical and

chemical characteristics of the scavenger. Three of those characteristics were considered for this study: 1) molecular charge, 2) molecular size, and 3) relative molecular shape.

Selection of Free Radical Scavengers

The amino acid cysteine has no toxic effects as part of a daily diet, and it becomes toxic only after it is administered on a daily basis at high concentrations [28-30]. Cysteine was also selected because the **charge** structure can be easily modified by blocking or adding charged substituent groups. Therefore, cysteine was chosen to analyze how the charge of a scavenger affects penetration into a bacterial pathogen. The most common form of cysteine is L-cysteine (LC) and is a zwitterionic molecule. For the positive and negatively charged form of cysteine, N-acetyl-L-cysteine (NAC) and L-cysteine-ethyl-ester (LCEE) were chosen, respectively. All three, LC, NAC, and LCEE are approximately the same size (~150Da) and all are the same linear shape with a cysteine backbone.

For the <u>size analysis</u>, a small, medium, and large molecular weight compound was selected. The small size molecule was Uracil (U), 112Da. Uracil is a ribonucleic base found in RNA. The medium size molecule was ascorbic acid (AA), 176Da. Ascorbic acid is more commonly known as vitamin C, and its antioxidant effects are well studied. The large size molecule was epigallocatechin gallate (EGCG), 458Da. Epigallocatechin gallate is the naturally occurring antioxidant compound found in Chinese green tea. The antioxidant activity of EGCG is at last 100 more times more effective than vitamin C and 25 times more effective than vitamin E at protecting cells

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and DNA from damage [31]. All three, U, AA, and EGCG have a neutral charge at pH 7 and all have approximately the same planar overall shape.

For the <u>shape analysis</u>, a globular and linear shaped molecule was chosen. The globular shaped molecule was trehalose (T). Trehalose is a disaccharide which is composed of two glucose molecules. The linear shaped molecule was glutathione (G). Glutathione is a tripeptide composed of glutamate, cysteine, and glycine that has numerous important functions within cells [32]. Both molecules, T and G, have a neutral charge at pH 7 and both are approximately the same size (~320Da). A fourth group was also investigated, regarding what could be categorized as another size analysis. Tryptophan (Trp) is an essential amino acid which is readily absorbed via dietary intake. A tripeptide of tryptophan (TTT) is easily obtained and would be advantageous to see if monopeptides penetrate more easily than a tripeptide.

Selection of Bacterium

Previous data has indicated that bacterial pathogens existing in an allograft are of the more "durable" and "hardy" variety. The cases discussed previously involved infection caused by a *Clostridium* strain of bacteria. *Clostridia* are anaerobic, Grampositive, spore-forming, rod-shaped bacteria [33]. The cell wall of Gram-positive bacteria is composed of a thick layer of murein (a peptidoglycan), compared to gramnegative bacteria that are which have a thin layer of murein, Figure 2.01 [34]. Therefore, it would be deduced that a free radical scavenger would already have limitations in crossing the cellular wall of a Gram-positive bacteria (a good thing). The outer cell wall

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of a Gram-negative bacteria, such as *E. coli*, is fairly permeable to smaller solutes below a molecular weight of approximately 400Da [35]. Such solutes can freely permeate via a concentration gradient [35]. However, under physiologic stress, the diffusion is slowed due to slowed bacterial activity [35].



Figure 2.01 Scheme of the cell wall of a gram-negative bacterium. LPS: lipopolysaccharide; PL: phospholipids; PG: peptidoglycan; OM: outer membrane; CM: cell membrane; PPS: periplasmic space; CP: cytoplasm [36].

Therefore, a worst-case-scenario is desired; such that a pathogen is highly susceptible to being protected. The optimum conditions for a scavenger to cross the cellular wall would occur when the cell is: 1) metabolically active, 2) aerobic, and 2) contains a gram-negative wall. The bacterial model selected for this study was *Escherichia Coli. E. coli* is a gram-negative, aerobic, non-spore forming bacterial model that is safe and reliable. Additionally, a dose of approximately 170Gy is sufficient for a

1-log inactivation of *E. coli* [37]. This allows for sufficient kill at a relatively low dose of gamma irradiation which means the samples spent less time in the irradiator.

Preparation of Free Radical Scavengers

Free radical scavengers were ordered from the appropriate vendors (Appendix K). Scavengers were prepared to the concentration as indicated in Table 2.02. All scavengers were in powder form, appropriate amount of scavenger was weighed (AB204, Mettler Toledo, Columbus, OH, USA) and added to a 25mm x 95mm vial with a screw cap (Fisher Scientific, St. Louis, MO, USA). Distilled deionized water was added to a volume of 20ml and the vial was shaken until the scavenger was completely in solution. The pH was measured (UB-10, Denver Instrument, Arvada, CO, USA) and adjusted to approximately 7.0 using concentrated sodium hydroxide and concentrated hydrochloric acid. The scavenger was then filter sterilized into a sterile vial with screw cap using a 0.20µm filter (Whatman, Clifton, NJ, USA) and 20ml syringe (Becton-Dickinson, Franklin Lakes, NJ, USA).

	Compound	Code	Concentration	Size	Charge	Shape
	Water (No Scavenger)	NS	-	-	-	-
ırge	L-Cysteine	LC	0.1M	121Da	Neutral	Planar
Cha	N-Acetyl-L-Cysteine	NAC	0.1M	163Da	Negative	Planar
	L-Cysteine-Ethyl-Ester	LCEE	0.1M	185Da	Positive	Planar
	Water (No Scavenger)	NS	-	-	-	-
Size	Uracil	U	0.01M	112Da	Neutral	Planar
	Ascorbic Acid	AA	0.01M	176Da	Neutral	Planar
	Epigallocatechin Gallate	EGCG	0.001M	458Da	Neutral	Planar
	Water (No Scavenger)	NS	-	-	-	-
hape	Trehalose	Т	0.1M	342Da	Neutral	Globular
S	Glutathione	G	0.1M	307Da	Neutral	Planar
peptide	Water (No Scavenger)	NS	_	-	-	-
	Tryptophan	Trp	25mM	204Da	Neutral	Planar
Tri	Trp-Trp-Trp	TTT	8.5mM	612Da	Neutral	Planar

Table 2.02 Concentrations of free radical scavengers tested.

Preparation of Bacteria Cultures

Wild type *E. coli* was obtained from the undergraduate Bioprocessing Laboratory at The University of Toledo (Toledo, OH, USA). The *E. coli* was stored at -80°C in 10% glycerol. Each vial contained 1.0ml at a concentration of approximately 1 x 10^{6} CFU/ml. The vials were allowed to warm to room temperature on the bench. In a sterile 150ml flask, 40ml of nutrient broth media (Appendix P) was added and brought to 37°C in a shaker incubator (G24, New Brunswick, Edison, NJ, USA). Thawed stock *E. coli* was transferred to the flask and the cells were allowed to proliferate for 24 hours in the shaker incubator at 37°C and 150rpm before being used to test scavengers.

Treatment of Bacteria with Scavengers

For the charge analysis, there were 32 treatment groups: 2 factors of irradiation (irradiated and non-irradiated), 4 factors of scavenger (no scavenger, LC, NAC, and LCEE), and 4 time points (0, 10, 20, and 40 hours).

For the size analysis, there were also 32 treatment groups: 2 factors of irradiation (irradiated and non-irradiated), 4 factors of scavenger (no scavenger, U, AA, and EGCG), and 4 time points (0, 10, 20, and 40 hours).

For the shape analysis, there were 24 treatment groups: 2 factors of irradiation (irradiated and non-irradiated), 3 factors of scavenger (no scavenger, T, and G), and 4 time points (0, 10, 20, and 40 hours).

For the tripeptide analysis, there were also 24 treatment groups: 2 factors of irradiation (irradiated and non-irradiated), 3 factors of scavenger (no scavenger, Trp, and TTT), and 4 time points (0, 10, 20, and 40 hours).

Using aseptic techniques, 2ml of each scavenger was added to its own individual vial with screw cap. Sterile deionized water (no scavenger, NS) was used in place of scavenger for the control samples. Continuing aseptic processing, 2ml of *E. coli* culture (grown for 24 hours) was added to each individual vial. Zero hours of incubation samples were immediately irradiated. The 10, 20, and 40 hour samples remained on the bench at ambient temperature for the duration of their incubation period, and then were irradiated. Samples containing scavenger and *E. coli* were irradiated to a dose of 500Gy (Isotopes, Inc., Westwood, NJ, USA) at room temperature. Controls remained on the bench at ambient temperature until the irradiated samples returned.



Picture 2.01 Gamma irradiation machine.

The irradiation machine, Picture 2.01, has a gamma irradiation delivery rate of 147Gy/hour. The desired dose of 500Gy was selected because it would allow for a

greater than 2-log inactivation of *E. coli*. This required the samples to be in the irradiator for 3.4 hours. At the completion of receiving 500Gy of gamma irradiation, the samples were serial diluted nine times at a five-fold dilution and then three times at a two-fold dilution with nutrient broth media; 100µl of the diluted sample was plated (n=4) on 100mm x 15mm Petri dishes (Fisher Scientific, St. Louis, MO, USA) containing agar media (Appendix O). The agar plates were incubated overnight at 37°C (Fisher Scientific, St. Louis, MO, USA) and a colony count was performed for each treatment group. Log concentration values were calculated by counting the colony forming units (CFU) on the plates and then equating the volume of cells plated with the dilution factor.

Statistical Analysis

A generalized multivariate ANOVA was performed to determine the significances of the effects of irradiation, duration, and scavenger. When significant differences existed among any two groups, the difference was tested by a Tukey's *post hoc* test. A difference at the level of p<0.05 was reported as significant and a difference at the level of 0.05<p<0.1 was reported as borderline significant. Dixon's outlier test was performed to determine if any concentration value was to be omitted at 95% confidence level. Those failing the outlier test are represented in red in the raw data section of the appendices indicating that they were omitted from the data set. Chapter Three

Results

All raw data can be found in Appendices A through J in this thesis. Values are reported in terms of log value of the concentration of the sample (log(concentration) CFU/ml). The labeling system of the samples was as follows, all data is presented in this form (the Appendix data also follows this convention):



E. coli Gamma Radiation Dose Response

A standard curve of *E. coli* log reduction (with no scavenger) was constructed to estimate log reduction at various doses of gamma irradiation, Figure 3.01. It was found that 1-log reduction occurred at a dose of approximately 300Gy.



Figure 3.01 Dose response log-reduction of E. coli.

Cysteine FRS Pilot Study

To assess the radioprotective effects of the cysteine based molecules, a pilot study was developed. The five identified cysteine based scavengers: L-cysteine (zwitterionic, LC), D-cysteine (zwitterionic, DC), N-acetyl-L-cysteine (negative, NAC), L-cysteinemethyl-ester, (positive, LCME), and L-cysteine-ethyl-ester (positive, LCEE) all at 0.1M were irradiated with *E. coli* to a dose of 500Gy, Figure 3.02. There was no prolonged incubation time of the scavengers with the *E. coli*, so this would be defined as an incubation time of zero hours. Results are reported as log-concentration values. The higher the log value, the more *E. coli* survived. The sample 500NS is *E. coli* with no scavenger treatment, therefore any groups having a higher concentration that than that group experienced a protective effect from the scavenger.



Figure 3.02 Cysteine pilot study; concentrations of *E. coli* after irradiation.

Charge Analysis

Figure 3.03 shows the effects of differently charged scavengers, Table 2.02, with *E. coli* irradiated to a dose of 500Gy. Log concentration values are reported with respect to the scavenger and time points 0, 10, 20, and 40 hours incubation. A scavenger treated group that has a higher log concentration value than its corresponding control groups indicates protection of the *E. coli* occurred. Those samples that attained a significant difference, p<0.05, than their corresponding control are indicated by a star. Shown in Table 3.01 are the reported p values for the respective parameters. Those p values below 0.05 indicate significant differences among the sample groups. Found in Appendix D is a pair-wise comparison chart between all samples, significance is reported as either significantly different (S) or not significantly different (NS) at a level of p<0.05.

Table 3.01 P values for parameters of charge analysis.

	Irradiation	Scavenger	Time	Scavenger- Irradiation	Scavenger- Time
Charge	0.000	0.000	0.000	0.000	0.000



Figure 3.03 Charge analysis; *E. coli* concentration after irradiation to 500Gy. Blue = 0 hours incubation; Green = 10 hours incubation; Orange = 20 hours incubation; yellow = 40 hours incubation. A sample marked with '*' indicates a significant difference from its control group ($500NS_{-}$).

Size Analysis

Figure 3.04 shows the effects of different size scavengers, Table 2.02, with *E. coli* irradiated to a dose of 500Gy. Log concentration values are reported with respect to the scavenger and time points 0, 10, 20, and 40 hours incubation. A scavenger treated group that has a higher log concentration value than its corresponding control groups indicates protection of the *E. coli* occurred. Those samples that attained a significant difference, p<0.05, than their corresponding control are indicated by a star. Shown in Table 3.02 are the reported p values for the respective parameters. Those p values below 0.05 indicate significant differences among the sample groups. Found in Appendix F is a pair-wise comparison chart between all samples, significance is reported as either significantly different (NS) at a level of p<0.05.

Table 3.02 P values for parameters of size analysis.

	Irradiation	Scavenger	Time	Scavenger- Irradiation	Scavenger- Time
Size	0.000	0.000	0.000	0.000	0.000



Figure 3.04 Size analysis; *E. coli* concentration after irradiation to 500Gy. Blue = 0 hours incubation; Green = 10 hours incubation; Orange = 20 hours incubation; yellow = 40 hours incubation. A sample marked with '*' indicates a significant difference from its control group ($500NS_{-}$).
Shape Analysis

Figure 3.05 shows the effects of different shaped scavengers, Table 2.02, with *E. coli* irradiated to a dose of 500Gy. Log concentration values are reported with respect to the scavenger and time points 0, 10, 20, and 40 hours incubation. A scavenger treated group that has a higher log concentration value than its corresponding control groups indicates protection of the *E. coli* occurred. Those samples that attained a significant difference, p<0.05, than their corresponding control are indicated by a star. Shown in Table 3.03 are the reported p values for the respective parameters. Those p values below 0.05 indicate significant differences among the sample groups. Found in Appendix H is a pair-wise comparison chart between all samples, significance is reported as either significantly different (S) or not significantly different (NS) at a level of p<0.05.

Table 3.03 P values for parameters of shape analysis.

	Irradiation	Scavenger	Time	Scavenger- Irradiation	Scavenger- Time
Shape	0.000	0.000	0.000	0.000	0.000



Figure 3.05 Shape analysis; *E. coli* concentration after irradiation to 500Gy. Blue = 0 hours incubation; Green = 10 hours incubation; Orange = 20 hours incubation; yellow = 40 hours incubation. A sample marked with '*' indicates a significant difference from its control group ($500NS_{-}$).

Tripeptide Analysis

Figure 3.06 shows the effects of a monopeptide versus a tripeptide scavenger, Table 2.02, with *E. coli* irradiated to a dose of 500Gy. Log concentration values are reported with respect to the scavenger and time points 0, 10, 20, and 40 hours incubation. A scavenger treated group that has a higher log concentration value than its corresponding control groups indicates protection of the *E. coli* occurred. Those samples that attained a significant difference, p<0.05, than their corresponding control are indicated by a star. Shown in Table 3.04 are the reported p values for the respective parameters. Those p values below 0.05 indicate significant differences among the sample groups. Found in Appendix J is a pair-wise comparison chart between all samples, significance is reported as either significantly different (S) or not significantly different (NS) at a level of p<0.05.

Table 3.04 P values for parameters of tripeptide analysis.

	Irradiation	Scavenger	Time	Scavenger- Irradiation	Scavenger- Time
Tripeptide	0.000	0.000	0.000	0.000	0.000



Figure 3.06 Tripeptide analysis; *E. coli* concentration after irradiation to 500Gy. Blue = 0 hours incubation; Green = 10 hours incubation; Orange = 20 hours incubation; yellow = 40 hours incubation. A sample marked with '*' indicates a significant difference from its control group ($500NS_{-}$).

Chapter Four

Conclusions

After examining the data, one initial conclusion can be drawn on the radiosensitivity of the *E. coli* itself without the presence of a scavenger (control samples). There appears to be a trend of increased resistance to gamma irradiation as time increases. In other words, as the incubation time increases more of the *E. coli* survives the 500Gy dose irradiation. For example in the charge data, at the 0 hour of incubation there is a 2.0-log reduction in the number of *E. coli* whereas at the 40 hours of incubation there is only a 0.8-log reduction in the number of *E. coli*, Figures 3.03 and 3.04.

This increased resistance to the irradiation dose could be the consequence of several factors. Firstly, as time increases, the *E. coli* are running out of nutrition resources, therefore, as a survival technique they are decreasing their metabolic activity. This decrease in metabolic activity results in the cell turning off non-essential cellular processes and implementing ways to conserve resources and enter a state of hibernation. *E. coli* cells become much smaller and almost spherical when they enter stationary phase

[38]. The cytoplasm volume is condensed; which would assume a decrease in intracellular water [38]. Additionally, during this stationary phase there is an increased demand for oxidation management [39]. Several genes are turned on that are devoted to synthesizing proteins with specific roles in the defense against oxidative stress [39]. In other words, as *E. coli* enters a stationary phase, they shrink by removing intracellular water and begin to make proteins with the specific purpose of fighting the oxidative stress of free radicals. Additionally, as incubation time increases and the food supply is depleted, the cells will become less mitotic and are therefore less susceptible to damaging radiation [34]. This would explain the observation of increased viability of *E. coli* in samples with long incubation times as the cells have begun to cope with their compromised environment.

In terms of the charge of a scavenger; the positively charged scavenger, LCEE, provided significant protection to *E. coli*, p<0.05. Positively charged LCEE was probably attracted to the overall negatively charged outer capsule of the *E. coli*. Most bacteria, including *E. coli*, contain an outer capsule which is composed mostly of polysaccharides which carries a negative charge [34]. Therefore, LCEE was attracted to *E. coli* and was allowed to enter the intracellular space and thus protected the cellular components from the oxidative stress of the gamma irradiation. The negatively and neutral charged scavengers are repelled from the capsule by the repulsion of charges, and therefore those scavengers do not enter the intracellular space and do not protect the bacteria. Thus, any positively charged scavenger would be a poor choice due to its inherent affinity for the negatively charged capsule of most bacteria. The obvious choice would then be a scavenger with a positive charge or at least a neutral charge.

Maintaining these guidelines will also avoid any interaction that the scavenger may have with the membrane; such that even if the scavenger does not cross into the intracellular space it will not protect the bacteria as a whole from the exterior of the cell. Samples of *E. coli* treated with scavenger alone (no irradiation) showed no decline in cellular viability. This proves that the decline in viability was a consequence of the irradiation and not of the scavenger itself. This data is shown in Appendix C.

In terms of the size of a scavenger; the smallest scavenger tested, U, did not offer any protection to the *E. coli*, p<0.05. The medium sized scavenger, AA, significantly protected the E. coli at 0 hours incubation time point, but no other time point. Therefore, aside from size, the *E. coli* selectively allowed the scavenger AA to enter the cell based on other parameters besides size. This selectivity was most likely a factor of chemical identity where it recognized AA as a useful molecule and allowed it to pass, where as the smaller U was identified as an unneeded entity and did not allow it to pass into the intracellular space. EGCG was shown to be too large of a molecule to diffuse readily into E. coli. This is illustrated as in Figure 3.04 where no significant protection was observed. Interestingly, EGCG has the second highest rate constant of the three scavengers tested for the hydroxyl radical, yet no protection was observed. AA has the highest rate constant for the hydroxyl radical and U the lowest rate constant of the group, AA only protected at the 0 hour incubation time point. Samples of *E. coli* treated with scavenger alone (no irradiation) showed no decline in cellular viability. This proves that the decline in viability was a consequence of the irradiation and not of the scavenger itself. This data is shown in Appendix E.

In terms of the shape of a scavenger; the globular scavenger T significantly protected *E. coli* at the 0 and 40 hours incubation time points, p<0.05. The linear scavenger, G, did not offer any significant protection at any of the incubation time points. Therefore, globular scavengers appear to be able to penetrate the bacterial membrane easier than a linearly shaped molecule. This would make sense; it is easier to navigate a tightly packed globular molecule down a channel than it is a linear molecule of the same molecular weight. The globular molecule would simply "tumble" down the channel where as a linear molecule would get stuck like a needle in the side of the channel. Another significant point is that G has a much higher rate constant for the hydroxyl radical than T; about 3-fold higher. Yet G did not protect at any time point, indicating again that regardless of rate constant for the hydroxyl radical physical and chemical features precede reaction rates. Samples of *E. coli* treated with scavenger alone (no irradiation) showed no decline in cellular viability. This proves that the decline in viability was a consequence of the irradiation and not of the scavenger itself. This data is shown in Appendix G.

In terms of a tripeptide molecule versus a singular amino acid; the tripeptide, TTT, significantly protected at 0 hours incubation time whereas the singular amino acid did not, p<0.05. Comparing the concentrations tested, the singular amino acid tryptophan was tested at a molarity of 24mM and the tripeptide, tryptohpan-tryptophan-tryptophan, was tested at a molarity of 8.4mM. This means that there were identical amounts of scavenging groups. Interestingly, the tripeptide was preferred over the singular amino acid with no prolonged incubation time. However, at 10, 20, and 40 hours incubation time both the singular amino acid and the tripeptide significantly protected the *E. coli*,

p<0.05. As illustrated in Figure 3.06, TTT pretty much protected at the same level for all time points whereas T was able to diffuse through into the bacteria in a time dependent manner; as time increases T protects the bacteria at higher levels. Samples of *E. coli* treated with scavenger alone (no irradiation) showed no decline in cellular viability. This proves that the decline in viability was a consequence of the irradiation and not of the scavenger itself. This data is shown in Appendix I.

To put these results into context of bone allograft sterilization with gamma irradiation; the addition of a scavenger has proven to alleviate biochemical and biomechanical stress to a bone allograft. However, selection of the proper scavenger is essential. From the results of this study, it would be advantageous to avoid positively charged scavengers due to their affinity for negatively charged envelops of bacteria, avoid molecules that cells may view as useful to uptake, avoid very small molecular weight molecules, and avoid globularly shaped molecules as they easily can diffuse into bacteria. Additionally, bacterial cells may show preference over one amino acid to the other, in this case showed to prefer tryptophan over L-cysteine as trpytophan protected and L-cysteine did not at same concentrations (0.1M) and similar rate-constants for the hydroxyl radical $(7.9 \times 10^9 \text{ M}^{-1} \text{s}^{-1} \text{ and } 8.5 \times 10^9 \text{ M}^{-1} \text{s}^{-1} \text{ for LC and Trp, respectively)},$ Figures 3.03 and 3.06. Thus, a well thought smart choice for a scavenger to add to a bone allograft tissue during gamma irradiation would be one that is negatively charged, linear in shape, and somewhat large (~250Da). This would allow for the protection of the collagen structure of the allograft tissue (as molecules below 300Da can penetrate bone fabric) but not allow for protection of the pathogens during irradiation.

$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$										Dose Res	ponse E. col	í Viability								
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$				Control			74Gy			147Gy			294Gy		4	141Gy			882Gy	
		DF	Count	Conc.	log(Conc.)	Count	Conc.	log(Conc.)	Count	Conc.	log(Conc.)	Count	Conc. lo	g(Conc.)	Count	Conc. Is	og(Conc.)	Count	Conc. Ic	og(Conc.)
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	÷	1,024																22	225,280	5.35
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	=	1 024																28	286,720	5.46
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	5	2,048																21	430,080	5.63
	71	2,048																20	409,600	5.61
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	ć,	4,096																9	245,760	5.39
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	ŧ	8,192													52:4	259,840	899 899	ى	491,520;	5.69
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	4	16,384													33.5	406,720	6.73	m	491,520	5.69
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	0	16,384													30:4	,915,200	6.69	-	163,840	5.21
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	ų,	32,768										42	13,762,560	7.14	8 2	621,440	6.42	2	665,360	5.82
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	₽	32,768										ន	17,367,040;	7.24	16,5	,242,880	6.72			
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	Ľ.	65,536										2	14,417,920	7.16	23	,276,800	6.52			
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	-	65,536										11	7 ,208,960	6.86	́с 9	932,160	6.59			
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	Ó	131,072	130	170,393,600	8.23	67	87,818,240	7.94	24	31,457,280	7.50	14	18,350,080	7.26	9 9	553,600	6.82			
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	2	131,072	124	162,529,280	8.21	26	127,139,840	8.10	26	34,078,720	7.53	15	19,660,800	7.29	99	553,600	6.82			
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	q	262,144	25	149,422,080	8.17	32:	83,886,080	7.92	0	34,078,720	7.53									
12 524 288 35 183 500 800i 8 26 10 52.428 800i 7.20 81.43.443.040i 7.20 31.5,728.640i 7.20 7.30 7.20 7.30 <td><u>D</u></td> <td>262,144</td> <td>5</td> <td>133,693,440</td> <td>8.13</td> <td>43</td> <td>112,721,920</td> <td>8.05</td> <td>15</td> <td>39,321,600</td> <td>7.59</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td>	<u>D</u>	262,144	5	133,693,440	8.13	43	112,721,920	8.05	15	39,321,600	7.59									
^{1.4} 524,288 38 199,229,440; 8.30 15; 78,643,200; 7.90 3; 15,728,640; 7.20 4, 20,971,520; 7.32 average 166,461,440 8.22 average 90,439,880 7.94 average 32,768,000 7.50 average 15,933,440 7.18 average 166,461,440 8.22 average 90,439,880 7.94 average 32,768,000 7.50 average 15,933,440 7.18 average 16,933,490 7.18 average 166,461,440 8.22 average 20,439,880 7.94 average 32,768,000 7.50 average 15,933,440 7.18 average 16,933,490 7.18 average 16,933,440 7.18 average 16,944 7.18 average	ć	524,288	35	183,500,800	8.26	10	52,428,800	7.72	8	41,943,040	7.62	m	15,728,640	7.20						
average 166,461,440 8.22 average 90,439,680 7.34 average 15,933,440 7.18 average stdev 23,490,794 0.062 stdev 26,371,217 0.134 stdev 9,193,746 7.50 average 15,933,440 7.18 average stdev 23,490,794 0.062 stdev 26,371,217 0.134 stdev 0,193,746 0.154 stdev 4,315,071 0.146 stdev N stdev N	71	524,288	38:	199,229,440	8.30	15	78,643,200	7.90	ε.	15,728,640	7.20	4	20,971,520;	7.32						
stdev 23,490,794 0.062 stdev 26,371,217 0.134 stdev 9,193,745 0.154 stdev 4,315,071 0.146 st N = N = N = 9,193,745 0.154 stdev 4,315,071 0.146 st			average	166,461,440	8.22	average	90,439,680	7.94	average	32,768,000	7.50	average	15,933,440	7.18 av	verage 4,	,587,520	6.64	average	398,429	5.56
			stdev	23,490,794	0.062	stdev	26,371,217	0.134	stdev	9,193,746	0.154	stdev	4,315,071	0.146 st	dev 1,	,383,777	0.137	stdev	185,310	0.208
			= N	Q		= N	Q		= N	۵	-	= N	ω	z		9	_	= N	:	

Appendix A

Dose Response E. coli Viability

N = number of colonies after irradiation

No = number of colonies prior to irradiation

		:	Surviving Fraction	
Dose	Conc. (CFU/ml)	Dose (Gy)	N/No	log(N/No)
	0 170,393,600	0	1	0
	162,529,280			
	149,422,080	74	0.5154	-0.288
	133,693,440		0.7823	-0.107
	183,500,800		0.5614	-0.251
	199,229,440		0.8431	-0.074
	•		0.2857	-0.544
	74 87,818,240		0.3947	-0.404
	127,139,840		ave	-0.278
	83,886,080		stdev	0.178
	112,721,920			
	52,428,800	147	0.1846	-0.734
	78,643,200		0.2097	-0.678
	•		0.2281	-0.642
14	47 31,457,280		0.2941	-0.531
	34,078,720		0.2286	-0.641
	34,078,720		ave	-0.645
	39,321,600		stdev	0.074
	41,943,040			
	15,728,640	294	0.0808	-1.093
			0.1069	-0.971
2	94 13,762,560		0.0965	-1.016
	17,367,040		0.0539	-1.268
	14,417,920		0.1000	-1.000
	7,208,960		0.0987	-1.006
	18,350,080		ave	-1.059
	19,660,800		stdev	0.110
4	41 3,112,960	441	0.0183	-1.738
	4,259,840		0.0262	-1.582
	5,406,720		0.0362	-1.441
	4,915,200		0.0368	-1.435
	2,621,440		0.0143	-1.845
	5,242,880		0.0263	-1.580
	-	-	ave	-1.603
8	82 225,280		stdev	0.163
	286,720			
	430,080	882	0.0013	-2.879
	409,600		0.0018	-2.753
	245,760		0.0029	-2.541
	245,760		0.0031	-2.514
			0.0013	-2.873
			0.0012	-2.909
			ave	-2.745
			stdev	0.177

Appendix I	3
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									a month				T					
		0ns0			OLC			0DC			ONAC			OLCEE			OLCME	
DF	Count	Conc.	log(Conc.)	Count	Conc.	log(Conc.)	Count	Conc. Ic	og(Conc.)	Count	Conc.	og(Conc.)	Count	Conc.	log(Conc.)	Count	Conc. Ic	g(Conc.
156,250	1 210	328,125,000	8.52															
156,250	_																	
156,250																		
156,250	_																	
312,500	86	306,250,000	8.49															
312,500	66	309,375,000	8.49															
312,500	120	375,000,000	6.57															
312,500	103	321,875,000	8.51															
625,000	14	87,500,000	7.94	R	218,750,000	8.34	8	218,750,000	8.34	398	225,000,000	8.35	ŝ	206,250,000	8.31	3712	231,250,000	83
625,000	1 23	143,750,000	8.16	Ŕ	225,000,000	8.35	2٤	231,250,000;	8.36 9	43.1	268,750,000;	8.43	34	212,500,000	8.33	41.2	256,250,000	8.4
625,000	49	306,250,000	8.49	37	231,250,000	8.36	34	212,500,000	8. 33	34	212,500,000	8.33	ŝ	206,250,000	8.31	ж Ж	25,000,000	с. С
625,000	61	381,250,000	85.8	Ŕ	225,000,000	8.35				R	187,500,000	8.27	R	206,250,000	8.31	8	243,750,000	ŝ
1,250,000	24	300,000,000	8.48	21	262,500,000	8.42	19	237,500,000	8.38	19:	237,500,000	8.38	17	212,500,000	8.33	18	25,000,000	с. Ю
1,250,000	2	87,500,000	7.94	17	212,500,000	8.3	21:	262,500,000	8.42	<u>6</u>	225,000,000	8.35	22	275,000,000	8.44	9	25,000,000	с. С
1,250,000	_			21	262,500,000	8.42	21	262,500,000	8.42	17	212,500,000	8.33 8	₽	225,000,000	8.35	16	000'000'000	ŝ
1,250,000	10	125,000,000	8.10	2	250,000,000	8.40	22	275,000,000	8.44	32.	287,500,000	8.46	19	237,500,000	8.3	18	25,000,000	00
	average	255,989,583	8.34	average	235,937,500	8.37 4	average	242,857,143	8.38	verage	232,031,250	8.36	average	222,656,250	8.35	average 2	28,906,250	6.9
	stdev	114,058,803	0.252	stdev	19,693,522	0.036	stdev	24,051,965	0.043 s	tdev	32,292,867	0.059	stdev	23,843,215	0.044	stdev	16,345,018	0.03
	= z	11		=	00	-	= 7	2	-	=	œ		= 7	œ		= Z	œ	

vunt Conc. log(Con		500LC			500DC		50	ONAC		ഹ	00LCEE		ഹ	00LCME	
	c.) Count	Conc. los	q(Conc.) C	ount	Conc. log	(Conc.)	Count	onc. log(C	onc.) Co	unt	Conc. loc	(Conc.)	Count	Conc. lo	I(Conc.)
							298: 9.5	312,500	6.97						
	123	3,843,750	6.58			_	145 4.5	331,250	6.66						
54 8,437,500 6.	66														
34 5,312,500 6.	73														
28: 4,375,000 6.	64														
55 8,593,750 6.	6														
9 7,031,250 6.	9	7,031,250	6.85	17:	13,281,250	7.12	19 14 6	343,750	7.17	53	42,968,750	7.63	44	34,375,000	7.51
	1			12	9,375,000	6.97	7 5,4	168,750	6.74				8	19,218,750	7.60
5 3,906,250 6.	.59 8	6,250,000	6.80	9	7,812,500	6.83	18 14 0	J62,500	7.15				58	50,781,250	7.71
10 7,812,500 6.	7	5,468,750	6.74	õ	14,062,500	7.15	16:12,5	200,000	7.10						
1 3,906,250 6.	59 2	7,812,500	6.89	m	11,718,750	70.7	3 11 2	718,750	7.07	<u>0</u>	39,062,500	7.59	12	46,875,000	7.67
8: 31,250,000 7.	.49 1	3,906,250	6.59	m	11,718,750;	20.7	5 19,4	531,250	7.29	33	89,843,750;	7.95	ę	70,312,500;	7.85
5 19,531,250 7.	29			2	7,812,500	6.83				<u>6</u>	70,312,500:	7.85	8	78,125,000	7.85
	-	3,906,250	6.59							12	46,875,000	7.67			
1 7,812,500 6.	68.			-	7,812,500	6.89	2 15 6	325,000	7.19				m	23,437,500	7.37
2: 15,625,000 7.	.19 2			ö		_				ü	46,875,000	7.67			
				÷	7,812,500	6.83	3 23 4	137,500	7.37	12:	93,750,000;	7.97	ö	46,875,000	7.67
	-	7,812,500	6.89	2	15,625,000	7.19	2, 15,6	325,000	7.19	œ	62,500,000	7.80	m	23,437,500	7.37
ige 10,299,479 6.	.92 average	5,753,906	6.74 av	erage	10,703,125	7.01 av	verage 13,5	332,386	7.08 ave	rage	61,523,438	7.77 a	verage	47,048,611	7.64
8,110,908 0.2	283 stdev	1,670,383	0.130 std	ev	2,970,349	0.120 st	dev 5,0	09,215	0.177 stde	N	21,369,926	0.147 s	tdev	18,712,437	0.185
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$ \begin{array}{ cccccccccccccccccccccccccccccccccccc$		625,000	8	518,750,000	8.71				186:1,150	5,250,000:	9.06			196:1	225,000,000	60.6				178: 1,112,500	000(0	9.6		
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sidev 716,70,855 0.287 statev 19,797,414 0.218 statev 116,201,712 0.039 statev 22,599,788 0.337 statev 164,025,925 0.067 statev 33,730,724 0.221 statev 52,839,745 0.000 statev 146,527 pt8 0.224 m 146,527 pt8 0.244 m 146,527 pt			average	1,383,593,750	9.07 av	verage 4	0,028,409	7.55 av	erage 1,266	5,406,250	9.10 ave.	rage 36,806,26	50 7.47	average 1,	228,906,250	3 60:6	verage 7	9,538,523	7.86 avera	ige 1,149,107	7,143	9.06 averag	e 334,288,194	8.48
M= 12 M= 11 M= 10 M= 10 M= 7 M= 9			stdev	718,370,855	0.287 st	dev 1.	9,797,414	0.218 std	lev 116	5,301,712	0.039 stde	v 23,599,75	96 0.337	stdev	164,035,925	0.057 s	tdev 🛛	3,730,724	0.221 stdev	52,839	9,745 0	.020 stdev	148,527,648	0.234
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Appendix C

		Conc.)							8.09	8.11	8.15	8.02	8.26	8.27	8.40	8.3	8.26	7.94	7.84	8. 8	7.88	8.05	7.94	8.30	8.14	0.182	
	EE10	c. log							7,500	2,500	80	2,500	000'0	2 000	:000	2,000	000 0	:000 0	0000	800	000'0	000	000 0	:000 C	0,469	2,871	16
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	0NAC	Conc.			4,218,750	9,531,250	4,218,750	1,875,000	8,125,000	5,000,000	7,187,500	8,750,000	1,250,000	8,750,000	4,375,000	1,875,000	5,000,000	7,500,000	3,750,000	000'000'0	2,500,000	000'000'0		2,500,000	7,179,276	1,320,127	19
	50	ount			31 2	25: 1	31.2	28:2	18:2	16:23	1	12:	10	9	11.0	7.2	4 28	9	7:4	9 8 9	1.1	4.5		1 1	erage 20	ev 1	
-	_	Conc.) (-			9.25	9.21	9.23	9.21	9.22 avv	0.019 std	ż
	9	log(C																			:000	:00	000	000	000	310	4
	ONAC	Conc.																			1,775,000,	1,625,000	1,687,500	1,612,500	1,675,000	74,302,	
		Count																			142	19	135	129	/erage	dev	
		(Conc.)			7.49	7.47	7.45	7.54	7.49	7.56	7.69	7.34	7.27	7.54	7.19	7.45	7.70	7.57	7.70	7.40	7.10	7.40	7.80	7.80	7.50 av	0.186 st	z
	C10	nc. log			000'0	7,500	2000	2,000	0000	2,500	2,500	000	000'0	2,000	2000	2000	0000	0000	:000	000	000'0	000	0000	0000	0,625	1,536	8
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	00ns10	Conc.							7 ,500,000	7 187 500	3,437,500	0.625,000	5,250,000	5,875,000	9,625,000:	5,625,000.	5,250,000	5 000 000	2,500,000	5 000 000	2,500,000	000'000'C	7,500,000	5,000,000.	9,492,188	9,060,545	16
	2	ount							56: 8.	43 6	47 7.	6 85 9	18	31 9	29 9	37:111	19 19 19	12 7.	10 10	20:12	9 11.	9	ŝ	2: 2:	rage 75	v 2	
	-	Duc.) C(-	_			_		9.28	9.27	9.26	9.28	9.27 avei	0.010 stde	z
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+		ount																			153 1;	149:1,	145 1.	151;11	Tage 1	94	
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	Conc.)										8.01	8.29	8.22		8.24	8.09	8.24	8.17	8.36	8.35	8.24	8.30	8.14	8.33	8.35	8.18	8.23	0.103	
EE20	c. log(2,000	000 (7 500		000 0	2,000	5,000	5,000	:000'0	000	000 C	000 0	000 0	000 0	000 0	:000'C	3,167	5,440	5
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	log(Conc.																		8.9	6.8	0.6	8.9	6.9	6.8	6.8	9.0	8.9	0.0	
CEE20	Conc.																		1,250,000	7,500,000	000,000,0	000'000'0	000'000'0	7,500,000	7,500,000	000'000'0	6,718,750	6,180,683	8
Ы	t																		149:93	150:93	168 1 05	152 95	72 90	71 88	67 83	80,1,00	age 93	9	
_	nc.) Coi		7.36	7.37	2.8	7.44	7.36	7.75	7 65		7.10	8	7.76	_	7.49	7.49	7.57	7.67	Z.10	8.9	7.27	_	7.40	7.80	7.57	7.57	7.45 aver-	.248 stdev	z
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AC20	onc. Is																		250,000	750,000	250 000	750,000	500,000	500,000	000 000	000'000'	000'000'	867,846	8
ß	ŭ																		217:1,356,	039: 1,493,	05: 1,281	83: 1, 143,	09: 1,362,	07:1,337	92:1,150	86: 1,075,	le 1,275,	140	
	c.) Cour						96	04	91	36	8	8	88	94	88	14	91	20	40	20	8	5	40	2	20	80	85 averag	11 stdev	z
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00LC2	Conc.						91,406,25(00'375'00	81 250 OD	89 843 750	85,937,500	96,875,000	76,562,500	87,500,000	71,875,000	37,500,000	81,250,000	18,750,000	25,000,000	50,000,000	62,500,000	31,250,000	25,000,000	37,500,000	50,000,000	62,500,000	18,593,750	31,797,628	77
10)	Count						117	140:1	104	115	55	62	49:	99	23	44 1	26	38:1	4	ö	Ę	21:1	5	m	4	ŝ	verage	dev	
	(Conc.)																		9.11	9.13	9.11	9.11	9.14	9.15		9.12	9.13 av	0.017 st	z
20	c. log																		000'0	0000	0000	000 0	000 0	000 0		0,000	12,857	2,248	2
OLC	Con																		5: 1,281,25	7:1,356,25	7:1,293,75	3 1,300,00	1:1,387,50	4: 1,425,0C		5 1,325,0C	1,338,35	53,46	
	Count																		20	21	8	8		÷	60	10	average	stdev	- z
	og(Conc.)						7.93	7.86	7 89	7.93	7.99	7.95	7.92	7.80	77.7	7.93	8.06	7.93	7.84	7.94	7.84	7.94	8.00	8.10	8.18	8.00	7.94	0.099	
0ns20	onc. It						156,250	875,000	125 MM	156.250	437,500	062.500	812,500	500,000	375,000	375,000	625,000	375,000	750,000	500,000	750,000	500,000	000'000	000'000	000'000	000'000	218,750	743,318	8
50	ant						109: 86,	92: 71.	100: 7B	109 85	8	27 88	83	40: 62	19: 59,	27 84,	37: 115,	27 84,	11	14 87,	11 88	14 87	8 100	10: 125,	12: 150,	8:100,	age 89,	/ 21,	
	nc.) Cot																		9.14	9.13	9.13	9.15	9.26	9.26	9.17	9.17	9.18 aven	.054 stdev	z
	log(Co																			8	8	8	8	8	8		8	00000	00
0ns20	Conc.																		,381,250,0	350,000,0	343,750,0	,425,000,0	837,500,0	812,500,0	487,500,0	,487,500,0	515,625,0	198,768,5	
-	Count																		221:11	216 1.	215:1	228:1,	147.1	145.1	119:1	119:1	erage 1	lev	
	ų.	3,125 3,125 3,125	15,625	15,625	15,625	15,625	78,125	78,125	78 125	78 125	56,250	56.250	56.250	56,250	12,500	12,500	112,500	12,500	725,000	725,000	25,000	725,000	20,000	20,000	20,000	20,000	,ve	stü	ż
	ā										É	ŕ	÷	÷	۳ 	m	m	e	6	ف	6	6	-	- -	4	<u>ج</u> 1			
		œ		2	-			d	D			¢	50			ç	2			+	=			ţ	2				

	(Conc.)							8.02	2.98	8.05	8.03	26.7	7.89	8.11	7.88	7.86	800	0.8	16.7	7.70	7.80	7.88		96'2	0.110	
0LCEE40	Conc. log							04,687,500	96,312,500;	10,937,500	06,250,000	93,750,000	78,125,000	28,125,000	75,000,000;	75,000,000	000'000'00	18,750,000:	87,500,000	50,000,000	62,500,000	75,000,000		90,729,167	21,565,627	15
20	Count							67 1	۵.	71:11	68:1.	8	35	41 1.	24	12	16:1.	19:1	14.	4	ώ	ü		average	stdev	=
	g(Conc.)															8.89	8.86	8.81		8.96	8.92	9.01	8.80	8.89	0.075	
DLCEE40	Conc. log															781,250,000	731,250,000	643,750,000:		912,500,000	837,500,000	,012,500,000:	637,500,000;	293,750,000	138,349,648	2
	ount															125	117	100		2		81:1	51:	erage	ev	
	Conc.) C							7.67	7.80	7.70	7.77	7.80	7.80	7.67	7.75	7.75	7.80	7.75	7.49	7.70	7.70	7.40	7.88	7.71 avv	0.119 std	z
NAC40	onc. log(875,000	500,000	:000'000	375,000;	500,000	500,000	875,000:	250,000	250,000	500,000	250,000:	250,000	000'000	000'000	:000'000	000'000	320,313	314,707	16
500	nt C							30 46	40: 62	32: 50/	38: 59,	20 62	20 62	15 46	18: 56,	95 56	10: 62	95 56,	5.31,	4: 50	4: 50	2 25	6: 75,	ge 53,	12,	
	ic.) Cou									_					_	8	8	70	8	92	98	8		.01 avera	J52 stdev	z
	log(Con															6	6	6		00	6	6		6	0.0	
0NAC40	Conc.															1,000,000,000	1,006,250,000	1 ,100 ,000 ,000	000'005'286	937,500,000	1,125,000,000	1,212,500,000		1,038,392,857	120,460,735	2
	Count															160	161	176	158:	67	6	26		rerage '	dev	
	(Conc.)							8.41	8.35	8.41	8.37	8.27	8.27	8.33	8.45	8.30	8.35	8.35	8.26	8.21	8.10	8.60	8.21	8.33 av	0.115 st	z
0LC40	Conc. log			·····				,250,000	875,000	812,500	812,500	2000'0005'	200,000	500,000	,250,000	000'000'	000/000	000/000	250,000	500,000	000/000	000'000'	500,000	,921,875	,620,977	9
20	u tu							164 256	142 221	165:257	149 232	60 187	60: 187	68:212	90;281	32 200	36 225	36:225	29:181	13 162	10: 125	32:400	13 162	ige 219	62	
, 0	IC.) Cot														_	60.	8	11	.10	90	8	.24	.15	.12 avera	056 stdev	z
	log(Con															6	6	6 	6	6	б П	6	6	6 [2	
LC40	Conc.															37,500,00	12,500,00	100'000'0C	38,750,00	50,000,00	100'000'0C	25,000,001	25,000,001	14,843,75	34,981,22	
	t															198 1,2	194 1 2	208:1,3	203: 1,2	92 1,1	96 1,2	138:1,7	114:1,4	ge 1,3	=	
	1c.) Cou							3.05	90	204	2.01	3.11	8	305	8	200	8	88	3.12	8	99	8	00	3.02 avera	060 stdev	z
	log(Cor							0	ω Q	ő	3	0	3 0	3	~ ;;;	3	3	2 :0	3 0	3	3 0		3	3 05	4 0.	9
00ns4(Conc.							10,937,50	14,062,50	00 375 00	03,125,00	28,125,00	00'000'00	12,500,00	84,375,00	00'000'00.	06,250,00	75,000,00	31,250,00	00'000'00	12,500,00	00'000'00.	00'000'00.	05,468,75	13,963,77	-
<u>م</u>	unt							71 1	73 1	70.1	66: 1	41 1	32 1	36	27	16:1	17 1	12	21: 1	8	9		8	age 1	>	
	nc.) Co									_				_		9.05	9.06	8.98	8.94	9.14	9.10	9.05	9.05	9.05 avei	.064 stde	z
	log(Co															00	8			8	, e	0		00	2	00
0ns40	Conc.															131,250,00	156,250,01	950,000,01	862,500,00	375,000,01	250,000,00	125,000,00	125,000,00	121,875,00	159,729,12	
	ount															181 1	186 1.	152: 5	138:	110:12	100:1,	-1 06	90:1,	rage 1.	- AB	
	с и	3,125 3,125 3,125 3,125	15,625	15,625	78.125	78,125	78,125	56,250	36,250	56,250	56,250	12,500	12,500	12,500	12,500	25,000	25,000	25,000	25,000	20,000	20,000	000'05	000'05	ave	stdt	z
	ð				-	2	~ ~	5	4	16	1£	ί	έ	è	è	5	5	2	5	125	1,2%	125	1,25			



Figure C.01 Charge analysis; *E. coli* concentration control groups non-irradiated Blue = 0 hours incubation; Green = 10 hours incubation; Orange = 20 hours incubation; yellow = 40 hours incubation. A sample marked with '*' indicates a significant difference from its control group (500NS_).

Appendix D

Charge Significance Chart

	OnsO	Ons10	Ons20	Ons40	500ns0	500ns10	500ns20	500ns40	OLcO	OLc10	OLc20	OLc40	500Lc0	500Lc10	500Lc20	500Lc40
OnsO		NS	NS	NS	S	S	S	S	NS	NS	NS	NS	S	S	S	S
Ons10	NS		NS	NS	S	S	S	S	NS	NS	NS	NS	S	S	S	S
Ons20	NS	NS	10	NS	S	S	S	S	NS	NS	NS	NS	S	S	S	S
UN\$40 500mc0	NS	NS	NS	c	5	S C	S	S	NS	NS	NS	NS	S	S NC	5 c	5
500nst0	S	S	S	S	S	3	NS	NS	S	S	S	S	S	S	NS	S
500ns20	S	S	S	S	S	NS		NS	S	S	S	S	S	S	NS	S
500ns40	S	S	S	S	S	NS	NS		S	S	S	S	S	S	NS	S
OLcO	NS	NS	NS	NS	S	S	S	S		NS	NS	NS	S	S	S	S
OLc10	NS	NS	NS	NS	S	S	S	S	NS	10	NS	NS	S	S	S	S
ULC2U 01 of 0	NS	NS	NS	NS	5 c	5	S	S	NS	NS	NC	NS	5	5	5 c	S c
500Lc0	S	S	S	S	NS	S	S	S	S	S	S	S	3	NS	S	S
500Lc10	S	S	S	S	NS	S	S	S	S	S	S	S	NS		S	S
500Lc20	S	S	S	S	S	NS	NS	NS	S	S	S	S	S	S		S
500Lc40	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	
ONACO	NS	NS	NS	NS	S	S	S	S	NS	NS	NS	NS	S	S	S	S
UNAC10 ONAC20	NS NS	NS NS	NS	NS	5 5	5 6	S C	5	NS NS	NS NS	NS NS	NS	5 5	5 6	5 5	5
ONAC40	NS	NS	NS	NS	S	S	S	S	NS	NS	NS	NS	S	S	S	S
500NAC0	S	S	S	S	NS	NS	NS	NS	S	S	S	S	S	S	NS	S
500NAC10	S	S	S	S	S	S	S	S	S	S	S	S	NS	NS	S	S
500NAC20	S	S	S	S	NS	S	S	S	S	S	S	S	NS	NS	S	S
500NAC40	S	S	S	S	NS	NS	S	S	S	S	S	S	NS	S	NS	S
OLCEEU Ol cee10	NS NS	NS	NS	NS	S	5	S	S	NS	NS	NS	NO	S	5	S S	S
OLcee20	NS	NS	NS	NS	ŝ	S	S	ŝ	NS	NS	NS	NS	ŝ	S	S	S
OLcee40	NS	S	NS	NS	S	S	S	S	NS	S	NS	NS	S	S	S	S
500Lcee0	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	NS
500Lcee10	S	S	S	S	NS	NS	NS	S	S	S	S	S	S	S	S	NS
500Lcee20	S	S c	S c	5	S	S NC	S	S	S	S	S	5	S	S	S NC	NS
300200040	J	J	J	J	J	NU	NU	NU	J	J	J	J	0	J	NU	J
	ONACO	00.0010	084020	ON A CAO	50004/00	5000 4010	50001000	50004040	01 0000	01 cont10	01 00020	0100040	5001 00010	5001 coc10	5001 coc00	5001.000/0
OnsO	ONACO NS	ONAC10	ONAC20	ONAC40 NS	500NACO S	500NAC10 S	500NAC20 S	500NAC40 S	OLcee0 NS	OLcee10 NS	OLcee20 NS	OLcee40 NS	500Lceel0 S	500Lcee10 S	500Lcee20 S	500Lcee40 S
Ons0 Ons10	NS NS	ONAC10 NS NS	ONAC20 NS NS	ONAC40 NS NS	500NAC0 S S	500NAC10 S S	500NAC20 S	500NAC40 S S	OLceeO NS NS	OLcee10 NS NS	OLcee20 NS NS	OLcee40 NS S	500Lceel0 S S	500Lcee10 S S	500Lcee20 S S	500Lcee40 S S
Ons0 Ons10 Ons20	NS NS NS	NS NS NS	ONAC20 NS NS NS	ONAC40 NS NS NS	500NAC0 S S S	500NAC10 S S S	500NAC20 S S S	500NAC40 S S S	OLceeO NS NS NS	OLcee10 NS NS NS	OLcee20 NS NS NS	OLcee40 NS S NS	500Lceel0 S S S	500Lcee10 S S S	500Lcee20 S S S	500Lcee40 S S S
0ns0 0ns10 0ns20 0ns40	NS NS NS NS NS	ONAC10 NS NS NS NS	ONAC20 NS NS NS NS	ONAC40 NS NS NS NS	500NAC0 S S S S	500NAC10 S S S S S	500NAC20 S S S S	500NAC40 S S S S S	OLceeO NS NS NS NS	OLcee10 NS NS NS NS	OLcee20 NS NS NS NS	OLcee40 NS S NS NS	500Lceel0 S S S S	500Lcee10 S S S S S	500Lcee20 S S S S S	500Lcee40 S S S S S
0ns0 0ns10 0ns20 0ns40 500ns0	NS NS NS NS S S	NS NS NS NS S S	0NAC20 NS NS NS S	ONAC40 NS NS NS NS S	500NAC0 S S S NS NS	500NAC10 S S S S S S S	500NAC20 S S S NS	500NAC40 S S S NS NS	OLceeO NS NS NS NS S	OLcee10 NS NS NS NS S	OLcee20 NS NS NS NS S	OLcee40 NS S NS NS S	500Lceel0 S S S S S S S	500Lcee10 S S S S NS	500Lcee20 S S S S S S S	500Lcee40 S S S S S NC
0ns0 0ns10 0ns20 0ns40 500ns0 500ns10 500ns20	0NAC0 NS NS NS NS S S S	ONAC10 NS NS NS S S S	0NAC20 NS NS NS S S S	0NAC40 NS NS NS S S S	500NAC0 S S S NS NS NS	500NAC10 S S S S S S S S S	500NAC20 S S S NS S S	500NAC40 S S S NS NS S	0Lcee0 NS NS NS NS S S S	0Lcee10 NS NS NS NS S S S	OLcee20 NS NS NS NS S S S	0Lcee40 NS S NS NS S S S	500Lceel0 S S S S S S S S S	500Lcee10 S S S NS NS NS	500Lcee20 S S S S S S S S S S	500Lcee40 S S S S S NS NS
0ns0 0ns10 0ns20 0ns40 500ns0 500ns10 500ns20 500ns40	0NAC0 NS NS NS S S S S S	0NAC10 NS NS NS S S S S S	0NAC20 NS NS NS S S S S S	0NAC40 NS NS NS S S S S S	500NACO S S S NS NS NS NS	500NAC10 S S S S S S S S S S S S S	500NAC20 S S S NS S S S S S S	500NAC40 S S S NS NS S S S S	OLceeO NS NS NS S S S S S	OLcee10 NS NS NS S S S S S	OLcee20 NS NS NS S S S S S	0Lcee40 NS NS NS S S S S S	500Lceel0 S S S S S S S S S S S S S	500Lcee10 S S S NS NS NS NS S S	500Lcee20 S S S S S S S S S S S S S	500Lcee40 S S S S NS NS NS
0ns0 0ns10 0ns20 0ns40 500ns10 500ns10 500ns20 500ns20 500ns40 0Lc0	ONACO NS NS NS S S S S S NS	ONACIO NS NS NS S S S S S S NS	ONAC20 NS NS NS S S S S S NS	0NAC40 NS NS NS S S S S NS	500NAC0 S S S NS NS NS NS NS S	500NAC10 S S S S S S S S S S S S	500NAC20 S S S NS S S S S S	500NAC40 S S S NS NS S S S	OLcee0 NS NS NS S S S S S NS	0Lcce10 NS NS NS S S S S S NS	OLcee20 NS NS NS S S S S S S NS	OLcee40 NS NS NS S S S S S NS	500Lceel0 S S S S S S S S S S S	500Lcee10 S S S NS NS NS S S S	500Lcee20 S S S S S S S S S S S S S	500Lcee40 S S S S NS NS NS S S
0ns0 0ns10 0ns20 500ns0 500ns10 500ns20 500ns20 0Lc0 0Lc10	ONACO NS NS NS S S S S S S S S S S	ONACIO NS NS NS S S S S S S NS NS	0NAC20 NS NS NS S S S S S NS NS	ONAC40 NS NS NS S S S S S S NS NS	500NAC0 S S NS NS NS S S S S	500NAC10 S S S S S S S S S S S S S	500NAC20 S S S NS S S S S S S S S	500NAC40 S S S NS NS S S S S S S	OLcee0 NS NS NS S S S S S NS NS	OLcee10 NS NS NS S S S S S S S S S S S S S	OLcee20 NS NS NS S S S S S S NS NS	0Lcee40 NS NS NS S S S S S S S S	500Lccel0 S S S S S S S S S S S S S	500Lcee10 S S S NS NS NS S S S S S	500Lcee20 S S S S S S S S S S S S S	500Lcee40 S S S S NS NS NS S S C
0ns0 0ns10 0ns20 500ns0 500ns10 500ns10 500ns40 0Lc0 0Lc10 0Lc20 0Lc40	ONACO NS NS NS S S S S S S S NS NS NS NS	ONACIO NS NS S S S S S S NS NS NS NS	ONAC20 NS NS NS S S S S S S NS NS NS NS	ONAC40 NS NS NS S S S S S S NS NS NS NS	500NAC0 S S NS NS NS NS S S S S S S	500NAC10 S S S S S S S S S S S S S	500NAC20 S S S S S S S S S S S S S S S S S S S	500NAC40 S S S NS NS S S S S S S S S S S S S S	OLcee0 NS NS NS S S S S S S NS NS NS NS NS	OLcee10 NS NS NS S S S S S S S NS NS NS NS	OLcee20 NS NS NS S S S S S S S NS NS NS NS	OLcee40 NS NS NS S S S S S S S S S S NS S NS	500Lccel0 S S S S S S S S S S S S S	500Lcee10 S S NS NS NS S S S S S S S S S S	500Lcee20 S S S S S S S S S S S S S	500Lcce40 S S S S S S NS NS NS S S S S S S S
0ns0 0ns10 0ns20 0ns40 500ns0 500ns10 500ns20 500ns40 0Lc10 0Lc20 0Lc40 500Lc0	ONACO NS NS NS S S S S S S S S NS NS NS NS S S	0NAC10 NS NS NS S S S S NS NS NS NS	0NAC20 NS NS NS S S S S NS NS NS NS	ONAC40 NS NS S S S S S S S NS NS NS NS S S	500NAC0 S S S NS NS NS NS S S S S S S S S S S	500NAC10 S S S S S S S S S S S S S	500NAC20 S S S S S S S S S S S S S	500NAC40 S S S NS NS S S S S S S S S S S S S S	OLcee0 NS NS S S S S S S S S S S S S S S S S	OLcee10 NS NS S S S S S S S NS NS NS NS S S	0Lcee20 NS NS S S S S S S S S NS NS NS NS S S	OLcee40 NS NS S S S S S S S S S NS S S NS S S S S S S S S S S S S S S S S S S S	500Lceel0 S S S S S S S S S S S S S	500Lcee10 S S S NS NS NS S S S S S S S S S S S S S	500Lcce20 S S S S S S S S S S S S S	500Lcce40 S S S S S S S NS NS S S S S S S S S S
0ns0 0ns10 0ns20 0ns40 500ns0 500ns10 500ns20 500ns40 0Lc10 0Lc20 0Lc20 0Lc40 500Lc0	0NAC0 NS NS NS S S S S S S NS NS NS NS S S S S	0NAC10 NS NS NS S S S S NS NS NS NS	0NAC20 NS NS NS S S S S S NS NS NS	0NAC40 NS NS NS S S S S S S S NS NS NS NS NS S S S S S S S S S S S S S S S S S S S	500NAC0 S S S NS NS NS NS S S S S S S S S S S S S S	500NAC10 S S S S S S S S S S S S S	500NAC20 S S NS S S S S S S S S NS N	500NAC40 S S NS NS S S S S S S S S S S S S S	OLcee0 NS NS S S S S S S S S NS NS NS NS NS S S S S S S S S S S S S S S S S S S S	OLcee10 NS NS S S S S S S S S NS NS NS NS S S S S S S S S S S S S S S S S S S S	0Lcee20 NS NS NS S S S S S S S S NS NS NS NS NS	0Lcee40 NS NS NS S S S S S NS S NS NS S S S S	500Lceel0 S S S S S S S S S S S S S	500Lcee10 S S S NS NS NS NS S S S S S S S S S S S S S	500Lcee20 S S S S S S S S S S S S S	500Lcee40 S S S S NS NS NS S S S S S S S S S S S S S
0ns0 0ns10 0ns20 0ns40 500ns10 500ns40 0Lc0 0Lc10 0Lc10 0Lc40 500Lc0 500Lc10 500Lc10	0NAC0 NS NS NS S S S S NS NS NS S S S S S S S S S S S S S	0NAC10 NS NS NS S S S S NS NS NS NS	0NAC20 NS NS NS S S S S S S NS NS NS NS S S S S S S S S S S S	0NAC40 NS NS NS S S S S S S S NS NS NS NS NS S S S S S S S S S S S S S S S S S S S	500NAC0 S S NS NS NS S S S S S S S S S S S S S	500NAC10 S S S S S S S S S S S S S	500NAC20 S S NS S S S S S S S S S NS N	500NAC40 S S NS NS S S S S S S S S S S NS S S S S S S S S S S S S S	0Lcee0 NS NS NS S S S S S NS NS NS NS NS S S S S S S S S S S S S S S S S S S S	0Lcce10 NS NS NS S S S S S S NS NS NS NS NS S S S S S S S S S S S S S S S S S S S	0Lcce20 NS NS NS S S S S S S S NS NS NS NS NS S S S S S S S S S S S S S S S S S S S	0Lcee40 NS NS S S S S S S S S S NS NS NS S S S S S S S S S S S S S S S S S S S	500Lceel0 S S S S S S S S S S S S S	500Lcee10 S S NS NS NS S S S S S S S S S S S S S	500Lcee20 S S S S S S S S S S S S S	500Lcee40 S S S NS NS NS S S S S S S NS S S S S S S S S S S S S S
0ns0 0ns10 0ns40 500ns0 500ns10 500ns40 0Lc0 0Lc10 0Lc20 0Lc40 500Lc0 500Lc0 500Lc10 500Lc10 500Lc20	0NAC0 NS NS NS S S S NS NS NS NS S S S S S S S S S S S S S	0NAC10 NS NS NS S S S S NS NS NS NS	0NAC20 NS NS S S S S S S NS NS NS NS NS S S S S S S S S S S S S S S S S S S S	0NACIO NS NS NS S S S NS NS NS NS S S S S S S S S S S S S S	500NAC0 S S NS NS NS NS S S S S S S S S S S S S S	500NAC10 S S S S S S S S S S S S S	500NAC20 S S NS S S S S S S S S S S S S S	500NAC40 S S NS NS S S S S S S S S S S S S S	0Lcee0 NS NS NS S S S S S NS NS NS NS NS S S S S S S S S S S S S S S S S S S S	0Lcee10 NS NS S S S S S S S S S S S S S S S S	0Lcce20 NS NS S S S S S S S NS NS NS NS S S S	0Lcee40 NS NS NS S S S S S S NS NS S S S S S S	500Lceel0 S S S S S S S S S S S S S	500Lcee10 S S NS NS NS S S S S S S S S S S S S S	500Lcee20 S S S S S S S S S S S S S	500Lcee40 S S S S S S S S S S S S S
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0ns0 0ns10 0ns40 500ns10 500ns10 500ns10 0Lc10 0Lc10 0Lc20 500Lc10 500Lc20 500Lc40 500Lc40 500Lc40 500Lc40 500Lc40 500NAC10 500NA	ONACO NS NS NS S S S NS NS NS NS NS NS S S NS NS NS NS S S S S S S S S S S NS NS NS NS NS	0NAC10 NS NS S S S S S S S	0NAC20 NS NS NS S S S S S S S S S S S S S	0NAC40 NS NS NS S S S S NS NS S S S S S S S S	500NAC0 S S S NS NS NS NS S S S S S S S S S S S S S	500NAC10 S S S S S S S S S S S S S	500NAC20 S S S S S S S S S S S S S	500NAC40 S S S S S S S S S S S S S	0Lcee0 NS NS S S S S NS NS NS S S S S S S S NS N	0Lcee10 NS NS NS S S S S NS NS NS NS S S S S S	0Lcee20 NS NS S S S S S S S S S S S S S S S S	0Lcee40 NS NS S S S S S S S S S S S S S S S S	500Lceel0 S S S S S S S S S S S S S	500Lcee10 S S S S S S S S S S S S S	500Lcee20 S S S S S S S S S S S S S	500Lcee40 S S S S S S S S S S S S S
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	(Conc.)	6.49	99	6.19	89	6.37	6.34	6.67	6.42	6.19	<u>6</u>	6.67	6.19	6.67	6.19		6.19			89	6.49		6.80		6.90					6.48	0.221	
00EGCG0	Conc. log	13,125,000	3 000 000 E	1 562 500	4,000,000	2,343,750	: 2,187,500	1 4 687 500	2,656,250	1,562,500	3,906,250	4,687,500	1,562,500	14,687,500	1,562,500		1,562,500			6,250,000	3,125,000		6,250,000		6,250,000					3,419,408	1,671,368	19
ũ	c.) Count	100	8	05	128	15	14	R	17	2	LO LO	G	2	m	-		+			2	-	98	-		-	00	95	94	8	98 average	37 stdev	= N
CG0	c. log(Con																					0000				i0000	000'00	0000	000'00	8 000'08	12,469 0.C	5
0EG(Int Con																					153: 956,25				80:1,000,00	71: 887,50	70 875,00	86; 1,075,00	ige 958,75	82,63	
-	(Conc.) Cou					7.06	7.00	7.01	7.09	7.15	7.24	7.25	7.01	6.97	7.27	7.10	6.80	7.19	6.97	6.97	7.49			6.80	6.80		7.10	7.40		7.08 avera	0.189 stdev	= z
00AA0	Conc. log					1,562,500	000'000'0	0,156,250	2,187,500	4,062,500	7,187,500	7,968,750	0,156,250	9,375,000	8,750,000:	2,500,000	6,250,000	5,625,000	9 ,375 ,000:	9,375,000	1,250,000			6,250,000	6,250,000		2,500,000	5,000,000		3,289,063	6,337,884	20
L)) Count					74:1	64 1	65 1	78:1	18:1	22 1	23:1	13:1	G	12 1	0	4	5	m	m	10:3	2	0	1	7		7 1 1	4 2:2		2 average 1	8 stdev	= Z
	log(Conc.																					0 8.9	0.8	0 8.9	0.8	00	0 8.9	0.8		8.9	33 0.06	7
DAAD	t Conc.																					50; 937,500,00	02: 637,500,00	45 906,250,00	50; 937, 500, 00	57 712,500,00	75: 937,500,00	70:875,000,00		e 849,107,1	123,027,50	
	Conc.) Coun	6.42	6.52	6.56	6.52	6.57	6.87	6.77	6.63	6.59	6.49	6.37	6.67	6.49	6.67	6.49	6.49	6.49	6.49	6.49			-	-	_					6.56 averag	0.120 stdev	=
500U0	Conc. log(,656,250	281,250	625,000	281 250	750,000	343,750	937,500	218,750	906,250	125,000	343,750	687,500	,125,000	687,500	,125,000	125,000	,125,000	125,000	125,000										768,092	,203,218	19
	Count	86	105 3	116.3	105:3	24:3	47 7	38:5	27:4	с 9	4	Ω Ω	9	23	т. Т.	2:3	2:3	<u></u>	-	- -		7			2		h.		-	average 3	r stdev 1	= N
	log(Conc.																					00: 8.9		00: 8.9	0.6 0.0	00	0.6 0.0	0.6	00: 8.9	9.9	98 0.06	7
000	Conc.																					2; 950,000,0	2	6; 787,500,0	9: 1,056,250,0	3 912,500,0	5; 1,187,500,0	1:1,137,500,0	7; 837,500,0	981,250,0	150,822,3	
	nc.) Count	6.54	6.36	6.56	6.44	6.61	6.19	6.54	6.45	5.89	5.89	6.37	5.89		6.67	6.19	6.49		6.49			5	J.	1	6	2	0)	5	œ	6.35 average	.260 stdev	" Z
0ns0	onc. log(Co	37,500	12,500	09/260	50,000	52,500	62,500	37,500	12,500	81,250	81,250	43,750	81,250		87,500:	62,500	25,000		25,000											72,266	03,279 0	16
50	Count C	110:3,4	74:2.3	115 3,5	88 2.7	26 4 0	10:1.5	22:3,4	18 2,8	1 7	1 7	3:2,3	1: 7		3:46	1 1.5	2;3,1		1.3,1		m									average 2,5	stdev 1,2	= N
	log(Conc.)																					8.54	8.53	8.99	00'6	8.95	9.05	9.10	9.01	8.90	0.226	
0ns0	Conc.																		-			350,000,000	337,500,000	968,750,000	1,000,000,000	887,500,000	1,125,000,000	1,250,000,000	1,025,000,000	867,968,750	341,076,249	00
	Count	.125	125	125	125	625	625	625	625	125	125	125	125	,250	250	,250	250	500	500	500	500	000	,000	000 155	,000 160	12 000	06 000	000 100	000	average	stdev	= Z
	ä	ľ	m	r.	m	15	5	5	5	8	82	8	۴	155	58	£	156	312	312	312	312	625	53	525	52	1,250	1,250	22	1,250			

Appendix E

_	(Conc.)	6.50 6.67 6.67	6.34 6.37 6.37	6.37	6.19	6.49 6.49	6.19	6.19	6.97			ç	0.43	9.9					7.10		7.10	6.59	0.295	
GCG10	Conc. log	187,500 687,500 687,500	187,500 593,750 343,750 243,750	343,750	562,500	125,000	562 500	562,500	375,000				:nnn'971	250,000					500,000		500,000	881,944	502,946	6
500E	Count 0	102 3, 150 4/ 150 4/	14 2, 23 3, 15 2, 40 5	3 2	2	2 0	1	1:1	0 0			,	τ ¹	9.1					1 12		1:12	erage 4/	ev 3	
	Conc.)					52.0	8.41	8.54	8.70	_	_		1	8.77	8.70	8.80	8.57	8.79	8.67	8.46	8.40	8.61 av	0.144 ste	z
G10	. log(500	000	,500	000					000	80	000	00	000	000	000'0	0000'0	8,750	8,041	12
OEGC	Conc					35156	259.37	348,43	200,000		,			109/199	200 000	631,250	375,000	612,500	462,500	287,500	250,000	430,466	137,218	
	Count					306	166	223	320					94	8	<u>1</u>	8	49	2E	8	20	average	stdev	I Z
	og(Conc.)		6.96	7.04	7.12	6.49 6.67	7.31	7.19	7.34		6.49	6.49	1.43	6.8	7.97	7.10	6.80			7.70		70.7	0.423	
0AA10	Conc. le		906,250	937,500	281,250	1.25,UUU 687,500	312,500	625,000	875,000		125,000	125,000	:nnn'n97	750,000	750,000	200 000	250,000			000'000		814,338	727,398	17
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	onc.) Co					8.57	8.52	8.58	8.71	8.47	8.10	9.40	8,1	8.59	8.50	8.67		8.56	8.24	8.42	7.80	8.43 ave	0.237 stde	z
0	. log(C					:UUU	005	2005	89	00	8	000		B	8	8		00	8	8	00	88	962	15
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	Count					800	21	24	Ř	85	4	00 f		۵	-0	~		175	-	6		average	stdev	z
	log(Conc.)	69 695 701	6.45 6.77 6.77	6.37		7 1	6.45	6.85	7.15	7.45	9.9	7.27	1			7.4C				7.1C		6.91	0.293	
00U10	Conc.	(,125,000 (,750,000 (,250,000 (,250,000	906,250 937,500	343,750	906 250 906 250	812,5UU	125 000	,812,500	625,000	125,000	250,000	220,000	inninne's			000,000				500,000		0,036,511	869'888'9	8
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001	Conc					14375	396.87	434,37	465,62	456,251	478,12			168/29	181 28			612,50	362,50	285,50	i 375,00	413,54	134,218	
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	g(Conc.)		6.66	6.74	7.41		7.24	6.83	7.04	7.19	6.49	6.49	b.49			6.80		7.70	7.10			6.95	0.366 t	-
0ns10	onc. lo		631,260	468,750	781,250	-	187,500	312,500	307,500	525,000	125,000	125,000	inniezi.			250,000		:000'00C	200,000			566,250	572,068	¥.
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	(T)								_	ى	_	_	-	/2	54	-		_	(0	m	en	Bave	4 stde	z
	onc.) (:		8 49	8.45	8.53	5.8	6.8			Ŀŀ	Di		8.0		8.8	88	8 4	8	8.5	0.15	
0	log(Conc.) (500: 8.49	000 8.45	500: 8.53	.000; 8.5I	000; 8.5					000	000		,000; 8.80	000; 8.8	000; 8.4	,000; 8.3	333 8.5	,880 0.15	12
0ns10	Conc. log(Conc.) (310.937 500; 8.49	281,250,000 8.45	342,187,500: 8.53	318,750,000: 8.51	365,625,000: 8.5				6.25.juuujuuu; 8.	437,500,000; 8.6	406,250,000 8.6		637,500,000 8.80	725,000,000: 8.8	300,000,000; 8.4	212,500,000: 8.3	405,208,333 8.5	152,878,880 0.15	12
0ns10	Count Conc. log(Conc.) (199i 310.937 500i 8.49	180 281 250,000 8.45	219: 342,187,500: 8.53	204 318,750,000: 8.5	117: 365,625,000; 8.5				84: 525,000,000; 8.	70: 437,500,000; 8.6	65: 406,250,000: 8.6		51 637,500,000 8.80	58 725,000,000 B.8	24: 300,000,000; 8.4	17: 212,500,000: 8.3	average 405,208,333 8.5	vtdev 152,878,880 0.15	N = 12
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	500ns10 0U10 500U10 0AA10 500AA10 0EGCG10 500EGCG10 500EGCG10 1	500ns10 0U10 500U10 0AA10 500AA10 0EGCG10 500EGCG10 aunt Conc. log(Conc.) Count Count Count	500ns10 0U10 500U10 0A10 0A10 500A10 0EGCG10 500EGCG10 500EGCG10	500ns10 0010 5000FGCG10 0A10 500A10 0EGCG10 500AGCG10 500AGCG10	500ns10 0010 500040 600A10 500A10 500A100 500A100 500A10	500ns10 0010 500U10 0EGCG10 500EGCG10 500EGCG10<	500ns10 00/10 500U10 0.6410 500A10 0EGCG10 500BGECG10 500BCECG10 50	500ns10 0U10 500u10 0EGGG10 500170 500A10 0EGGG10 500170 500170 5002010 500170 5002010 500170 500170 5002010 5001700 5002010 </td <td>500ns10 0010 500010 0010 500010 0000000 50000000 50000000 50000000 50000000 50000000 50000000 50000000 50000000 50000000 50000000 50000000 50000000 50000000 500000000 50000000 50000000 50000000 50000000 50000000 50000000 50000000 50000000 50000000 5000000000000 5000000000000000000000000000000000000</td> <td>$\begin{array}{ c c c c c c c c c c c c c c c c c c c$</td> <td>$\begin{array}{ c c c c c c c c c c c c c c c c c c c$</td> <td>$\begin{array}{ c c c c c c c c c c c c c c c c c c c$</td> <td>$\begin{array}{ c c c c c c c c c c c c c c c c c c c$</td> <td>$\begin{array}{ c c c c c c c c c c c c c c c c c c c$</td> <td>$\begin{array}{ c c c c c c c c c c c c c c c c c c c$</td> <td>$\begin{array}{$</td> <td></td> <td></td> <td></td> <td>$\begin{array}{ c c c c c c c c c c c c c c c c c c c$</td> <td></td> <td></td> <td>$\begin{array}{$</td> <td>500nation 00010 00110 5000110 000100 5000110 0001000 5000110 0001000 50001000 50001000 50001000 50001000 50001000 50001000 50001000 500010000 50001000 500010000 500010000 50001000000000000000000000000000000000</td>	500ns10 0010 500010 0010 500010 0000000 50000000 50000000 50000000 50000000 50000000 50000000 50000000 50000000 50000000 50000000 50000000 50000000 50000000 500000000 50000000 50000000 50000000 50000000 50000000 50000000 50000000 50000000 50000000 5000000000000 5000000000000000000000000000000000000	$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	$ \begin{array}{ $				$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$			$ \begin{array}{ $	500nation 00010 00110 5000110 000100 5000110 0001000 5000110 0001000 50001000 50001000 50001000 50001000 50001000 50001000 50001000 500010000 50001000 500010000 500010000 50001000000000000000000000000000000000

		(Conc.)		6.80	7.19	6.93	7.10	7.04	89	7.04			7.04	7.42	7.31			6.49	7.10	7.57	7.10	89	7.57	7.57	7.70	7.40	7.40	7.17	0.321	
	GCG20	nc. log(:000'0	2,500	19,750	6,250	17,500	00000	17,500			17,500	32,500	2,500			5,000	000'0	000'0	000'0	000'0	:000'0	000'0	000'0	000'00	:000'0	11,250	7,039	8
	500E	unt Co		40: 6,25	98:15,31	92 92 92	81:12,65	14:10,95	8 6,25	14:10,95			7:10,95	17:26,56	13:20,31			1: 3,12	4:12,50	6:37,50	2: 12,5C	1: 6,25	6:37,50	3:37,50	4:50,00	2:25,00	2:25,0C	age 18,76	v 13,17	
	_	onc.) Coi										_								9.01				9.01	9.01	8.40	8.69	8.82 aver	0.275 stdev	<u></u>
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	0EGC(Conc.																		1,025,000,				1,012,500	1,025,000	250,000	487,500	760,000,	366,934,	
		Count																		164				8	68	20	ଞ	average	stdev	=
	_	og(Conc.)		7.72				7.77				7.64	7.64	7.42	7.47	7.27	6.80	7.49	7.80	7.10	7.80	7.75	7.10	7.57	7.57		7.10	7.47	0.299	
	DOAA20	Conc. I		031,250				,593,750				750,000	750,000	562,500	687,500	750,000	250,000	250,000	200,000	200,000;	500,000	,250,000	500,000	200,000	500,000		500,000	551,471	864,811	17
	5	Count		333152				BG G/				28:43	28:43	17 26	19:29	6:18	2: 6	10:31	20:62	2:12	10:62	9:56	2:12	3:37	3:37		1:12	rerage 35	dev 18	
	-	(Conc.) (8.99	8.76	8.84	8.61					8.88	8.76	8.79	8.62	8.78 av	0.129 stv	z
	A20	nc. log														75,000	25,000	:000'0(20'000					000'00	:000'0(:000'0(000'00	13,750	39,169	8
	P0	nt Co														315: 984, 37	185: 578, 12	220:687,50	130:406,25					61:762,50	46:575,00	49:612.50	33:412.50	ge 627,34	188,86	
	_	nc.) Cou	7.18					33	.45			-	, 61	8	,34	. 70	. 34	6.49		6.80			.70		7.10	7.10		7.27 avera	377 stdev	-
	20	log(Co	8						8				8	8	8	8	8	8	8						8	8		12	94	14
	500U	Conc.	15,031,22				0 0 100	35,156,2	28,125,00				40,625,00	42,187,50	21,875,00	50,000,00	21,875,00	3,125,00	6,250,00	6,250,00			50,000,00		12,500,00	12,500,00		24,678,5;	16,441,19	
Jara		Count	481					4	æ			2	2	27	1	đ	2	-		-	Ψ		0	01	-	-		average	ostdev	=
nour Size		log(Conc.										9.5 8	8.4	69 8	8.9	8.4	9.9			7.9	₩ 8	7.9	9.6	9.1	80	8.2		8.4	0.36	
77	0U20	Conc.										5,000,000	0,625,000	5,937,500	8,750,000	5,625,000	8,125,000			1,250,000	000'000'0	1,250,000	8,750,000	2,500,000	5,000,000	5,000,000		8,293,269	7,455,984	13
		unt										240: 37	186. 25	215 3G	204: 31	86: 26	265: 82			13:	24 15	Ξ Ξ	67: 41	105:1,31	54 67	14: 17		rage 40	N N	
		Conc.) Co	6.91 6.87	7.27	7.16	7 07		7.04	7.12	7.25	7.63	7.61	7.31	7.59	7.54	6.97	7.10	7.45	7.34	7.80	8.07	7.97		8.14	8.10	7.57	7.57	7.44 ave	0.383 stde	
	1s20	c. log((5,000	000	250	000		, 500	250	3,750:	3,750	000	500	500	000	000	000	2000	000	000	000	000'u		000	:000'u	:000	000	1,802	162'.	24
	500n	t Cone	50 8,125 35 7,343	20: 18,750	33: 14,531	76 11,875		14 10,937	13,281	23 17,968	55: 42,968	26:40,625	13: 20,312	25 39,062	22: 34,375	3 9,375	4: 12,500	9: 28,125	7: 21,875	10: 62,500	19:118,750	15; 93,750		11: 137,500	10: 125,000	3: 37,500	3: 37,500	e 40,186	38,981	
		count	2	1						. 1	~	. 1		- 1	. 1	50	2	20	66	22		92	ß	50	5	22	8	57 averag	53 stdev	z
		log(Conc														9.0	9.0	9.6	9,6	1.8		8	.8	3.6		1: 7.5	3.6	8	0.46	
	0ns20	Conc.														53,125,000	46,875,000	71,875,000	31,250,000	58,750,000	31,250,000	91,250,000	91,250,000	37,500,006	12,500,000	37,500,000	37,500,000	53,385,417	12,475,159	12
		ount														337 1.0.	335:1,0.	375: 1,1.	314 9.	ଟ ଓଡ଼	29 11	73	61: 9	99 14	9	m	9 13	srage 54	ev 4	
		0F C	3,125 3,125 3,125 3,125	15,625	5,625	15,625	15,625	78,125	78,125	78,125	78,125	56,250	56,250	56,250	56,250	12,500	12,500	12,500	12,500	25,000	25,000	25,000	25,000	20,000	000'05	000'05	000'05	ave	stde	z
		_		1.000	_			\sim_{i}	\sim	\sim	\sim	-01	$\underline{\circ}$	-40	-92	L The second	1	Σ	Σ	123	S.	52	12	52	50	:53	:53			

		(Conc.)		7.06		6.67	6.59	6.49	5.89	7.19	7.24	7.19		6.97	7.19	6.80	6.49					7.10		7.10	7.10	6.87	0.379	
	0EGCG40	Conc. log		11,562,500		4.687,500	3,906,250:	3,125,000	781,250	15,625,000	17,187,500:	15,625,000		9,375,000	15,625,000:	6,250,000	3,125,000					12,500,000		12,500,000	12,500,000	9,625,000	5,509,668	15
	50	Count		74		9	50	4	+	Ę	1	Ę		m	ΥΩ	7	+					÷		+	-	average	stdev	=
		g(Conc.)		i														8.35	8.43			9.28	9.24	8.42	8.46	8.70	0.439	-
	EGCG40	Conc. lo																25,000,000	68,750,000			12,500,000	20 000 000	62,500,000	87,500,000	84,375,000	112,786,007	ø
-	0	ount																36	4			153 1,5	140:1.7	31:	2	erage 7	ev 8	
-		Conc.) (8.00	7.88	7.90	7.69	7.73	7.64	7.54	7.34	8.14	8.40	8.27		7.40	7.80	8.0	8.21	7.86 av	0.315 std	ż
-	9440	nc. log(000/00	0000	37,500	37,500	55,000	00000	⁷⁵ ,000	⁷ 5,000:	00000	00000	00000		:000/00	00000	00000	000'00	33,333	23,626	15
_	500/	nt Co								64; 100,00	48: 75,00	51 79,66	31 48,40	17 53,11	14: 43,75	11: 34,37	7 21,87	22 137,50	40:250,00	30: 187,50		2: 25,00	5: 62,50	8:100,00	13 162,50	ge 92,06	8	
-		nc.) Cou												3.93				9.02	9.07	3.98	9.12					3.02 avera	076 stdev	= Z
	0	log(Co												000				:000	8	8	8					80	395	S
	0AA4	Conc.												850,000,0				1,037,500,0	1,187,500,0	920,000,036	1,325,000,0					1,070,000,0	188,869,9	
		Count												272				166	190	152	212	172				average	stdev	=
		og(Conc.)		7.14	7.13	7.60	7.31			7.59	7.78	7.75	7.66	7.67	6.80	7.27	7.10	7.70	6.80	7.49	7.70	7.57	7.10	7.70		7.40	0.316	
	00U40	Conc. Is		8,750,000	3,437,500	9.843.750	0,312,500			9,062,500	0,937,500	5,250,000	5,312,500	6,875,000	6,250,000	3,750,000	2,500,000	000 000 0	5,250,000	250,000	000,000,0	200'009'	5,500,000	000'000'0		390,625	3,109,602	8
	S	Count		88:10	88	51:30	26 20			25 30	39:EE	39:9E	29:46	15:46	2: E	9	4:12	992	-	5.3	8:50	3:37	1	4:50		erage 31	lev 18	
		(Conc.)								8.70	88	8.70	8.14	8.51	8.49	8.60	8.74	9.29				9.21	9.12			8.74 av	0.343 st	z
	40	nc. log								175,000	37,500:	00000	000'00	75,000	20/000	00000	000'00	000'00				:000'00	00000			48,864	G7 ,593	÷
	0	t Coi								118; 496,8	03; 473,4	20; 500,0	88: 137,5	03: 321,8	98; 306,2	28: 400,0	76: 550,0	10:1,937,5				30; 1,625,0	06: 1,325.0			6'22'6	602.0	
		.) Count		212	. 4 00	5	:0	10	12	m	(r)	m	_	-		-	-	m						0	¥	l2 average	3 stdev	= z
		log(Conc		7.6	7.7	1 7.2	7.4	1.5	0.6													3.8	0: 8.7	9.1	0.C	1 8.C	0.72	0
	00ns40	Conc.		32,968,750	55,000,000 15,156,250	17,968,750	31,250,000	35,156,250	105,468,750													762,500,000	300,000,000	250,000,000	387,500,000	336,627,604	461,904,511	1
	ц)	Count		211 200	362	33	40	45	135													61	48: t	1001	87 1.1	erage :	lev L	
		(Conc.) (888	8.80	88		8.89	8.94	8.76			8.62	8.91	8.57	8.80 av	0.129 stc	z
	340 340	nc. log												000/00	00000	000/00		00000	0000	20,000			000'00	000'00	000'00	51,111	98,816	ຫ
	0ns	t Con												40: 750,01	04: 637,51	16: 675,01		24: 775,01	40: 875,01	93: 581,2		48	33: 412,5t	65 812,51	30 375,01	e 654,8t	173,1%	
		Count	***	Kix	3 KJ K	12	5	5	52	8	8	8	8	20	30 21	20	8	1,	-	8	8	1	8	8	8	average	stdev	" Z
		Ы	0,0,0,0 2,2,0,0 2,2,0,0	15.6. 15.6.	100 100 100 100 100	78.12	78,12	78,1,	78,12	156,24	156,24	156,25	156,25	312,50	312,50	312,50	312,50	625,00	625,01	625,00	625,00	1,250,00	1,250,00	1,250,0(1,250,00			
t				Å	~		і с	i) o	i			نت و	i 2)	 ‡				 ç	2	i			



Figure E.01 Size analysis; *E. coli* concentration control groups non-irradiated Blue = 0 hours incubation; Green = 10 hours incubation; Orange = 20 hours incubation; yellow = 40 hours incubation. A sample marked with '*' indicates a significant difference from its control group (500NS_).

Appendix F

Size Significance Chart

	0ns0	500ns0	000	500U0	OAAO	500AA0	0EGCG0	500EGCG0	Ons10	500ns10	0U10	500U10	0AA10	500AA10	0EGCG10	500EGCG10
0ns0		S	NS	S	NS	S	NS	S	NS	S	NS	S	S	S	NS	S
500ns0	S		S	NS	S	S	S	NS	S	S	S	S	S	S	S	NS
0U0	NS	S		S	S	S	NS	S	NS	S	NS	S	S	S	NS	S
500U0	S	NS	S		S	S	S	NS	S	NS	S	NS	S	S	S	NS
OAAO	NS	S	S	S		S	NS	S	NS	S	NS	S	NS	S	NS	S
500AA0	S	S	S	S	S		S	S	S	NS	S	NS	S	NS	S	S
OEGCGO	NS	5	NS	5	NS	5	0	5	NS	S	NS	5	NS	S	NS	5
500EGCG0	S	NS	S	NS	5	5	S NC	0	5	5	S NC	S	S	5	S NC	NS C
UIIS10 500mc10	1N5 C	5 c	C/I	5 NC	NO C	5 NC	ND C	5 c	6	3	ND C	S NC	NS C	5 NC	ND C	5 NC
01110	NS	S	NS	S	NS	S	NS	S	NS	S	J	S	NS	S	NS	S
500010	S	S	S	NS	S	NS	S	S	S	NS	S	Ű	S	NS	S	NS
0AA10	S	S	S	S	NS	S	NS	S	NS	S	NS	S	-	S	NS	S
500AA10	S	S	S	S	S	NS	S	S	S	NS	S	NS	S		S	S
0EGCG10	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S		S
500EGCG10	S	NS	S	NS	S	S	S	NS	S	NS	S	NS	S	S	S	
Ons20	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S
500ns20	S	S	S	S	S	NS	S	S	S	S	S	S	S	NS	S	NS
0020	NS c	5	No	5 c	No	5 NC	NS c	5 c	NO	S NC	NS C	S NC	No	5 NC	NS C	5 c
00020	0 NC	0 0	0 NC	0 0	S NC	NO C	0 NC	3 6	0	NO C	J NC	c no	3 NC	l NO C	J NC	0 0
5004420	S	NS	S	S	S	NS	S	S	S	NS	S	S	S	NS	S	S
0EGCG20	NS	S	NS	S	NS	NS	NS	S	NS	S	NS	S	NS	S	NS	S
500EGCG20	S	S	S	NS	S	NS	S	S	S	NS	S	NS	S	NS	S	S
Ons40	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S
500ns40	S	S	S	S	S	S	S	S	S	S	S	S	NS	S	S	NS
0U40	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S
500U40	S	S	S	S	S	NS	S	S	S	S	S	S	S	NS	S	S
0AA40	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	S	S
DUUAAAU	5 NC	5 c	5 NC	5 6	S NC	NO C	5 NC	5 6	5 6	5 C	5 NC	5 6	5 NC	5 NC	5 NC	5 C
500FGCG40	S	S	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS
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	000	500-+00	01100	5001100	04400	5004400	000000	500500000	0==10	500	01140	5001140	04440	5004440	0500040	500500040
Incl	Ons20	500ns20	0U20	500U20	0AA20	500AA20	0EGCG20	500EGCG20	Ons40	500ns40	OU40	500U40	0AA40	500AA40	0EGCG40	500EGCG40
0ns0 500ns0	Ons20 NS S	500ns20 S	OU20 NS S	500U20 S	0AA20 NS S	500AA20 S NS	0EGCG20 NS S	500EGCG20 S	Ons40 NS S	500ns40 S	0U40 NS S	500U40 S S	0AA40 NS S	500AA40 S	OEGCG40 NS S	500EGCG40 S
OnsO 500nsO OUO	Ons20 NS S NS	500ns20 S S S	OU20 NS S NS	500U20 S S S	0AA20 NS S NS	500AA20 S NS S	0EGCG20 NS S NS	500EGCG20 S S S	Ons40 NS S NS	500ns40 S S S	OU40 NS S NS	500U40 S S S	OAA40 NS S NS	500AA40 S S S	0EGCG40 NS S NS	500EGCG40 S S S
0ns0 500ns0 0U0 500U0	Ons20 NS S NS S	500ns20 S S S S	0U20 NS S NS S	500U20 S S S S	0AA20 NS S NS S	500AA20 S NS S S	OEGCG20 NS S NS S	500EGCG20 S S S NS	0ns40 NS S NS S	500ns40 S S S S	0U40 NS S NS S	500U40 S S S S	OAA40 NS S NS S	500AA40 S S S S	OEGCG40 NS S NS S	500EGCG40 S S S NS
0ns0 500ns0 0U0 500U0 0AA0	0ns20 NS S NS S NS	500ns20 S S S S S	0U20 NS S NS S NS	500U20 S S S S S S	0AA20 NS S NS S NS	500AA20 S NS S S S S	0EGCG20 NS S NS S NS	500EGCG20 S S NS S S	0ns40 NS S NS S NS	500ns40 S S S S S S	0U40 NS S NS S NS	500U40 S S S S S S	OAA40 NS S NS S NS	500AA40 S S S S S S	0EGCG40 NS S NS S NS	500EGCG40 S S S NS S
0ns0 500ns0 0U0 500U0 0AA0 500AA0	0ns20 NS NS S NS S S	500ns20 S S S S S NS	0U20 NS S NS S NS S	500U20 S S S S NS	0AA20 NS S NS S NS S S	500AA20 S NS S S S NS	0EGCG20 NS S NS S NS NS	500EGCG20 S S NS S NS NS	0ns40 NS S NS S NS S S	500ns40 S S S S S S S S	0U40 NS S NS S NS S S	500U40 S S S S NS	0AA40 NS S NS S NS S S	500AA40 S S S S S NS	0EGCG40 NS S NS S NS S S	500EGCG40 S S S NS S NS NS
0ns0 500ns0 0U0 500U0 0AA0 500AA0 0EGCG0	0ns20 NS S NS S NS S NS S	500ns20 S S S S NS S NS	0U20 NS S NS S NS S NS S NS	500U20 S S S S NS S	0AA20 NS S NS S NS S NS S NS	500AA20 S NS S S S NS S	0EGCG20 NS NS S NS NS NS NS	500EGCG20 S S NS S NS S NS S	0ns40 NS NS NS S NS S NS	500ns40 S S S S S S S S	0U40 NS S NS S NS S NS S NS	500U40 S S S S NS S	0AA40 NS S NS S NS S NS S NS	500AA40 S S S S NS S NS	0EGCG40 NS S NS S NS S NS S NS	500EGCG40 S S NS S NS S NS S S NS S S NS S S S S S S S S S S S S S
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0ns0 500ns0 000 50000 00A0 500A0 0EGCG0 500EGCG0 0ns10 500ns10 0110	0ns20 NS S NS S NS S NS S NS S NS	500ns20 S S S S NS S S S S S S S S S S S S S	0U20 NS S NS S NS S NS S NS S NS	500U20 \$ \$ \$ \$ NS \$ \$ \$ NS \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$	04420 NS S NS S NS S S S S S S S S S S	500AA20 S NS S S NS S S S NS S S	0EGCG20 NS S NS S NS NS S S NS S S NS	500EGCG20 S S NS S NS S NS S NS S	0ns40 NS NS NS S NS S NS S NS S NS	500ns40 S S S S S S S S S S S S S	0140 NS S NS S NS S NS S NS S NS	500U40 S S S S NS S S S S S S S S S S S S S	0AA40 NS S NS S NS S NS S NS S NS	500A440 S S S S S S S S S S S S S S S S S	0EGCG40 NS S NS S NS S S S S S S S S S S S	500EGCG40 S S NS S NS S NS S NS S NS S S
0ns0 500ns0 000 50000 0AA0 500AA0 0EGCC0 0ns10 00ns10 0010 5000s10	0ms20 NS NS S NS S NS S NS S NS S NS S S NS	500ns20 S S S S NS S S S S S S S S S S S S S	0020 NS NS NS NS S NS S NS S NS S NS S S NS S S	500U20 S S S S NS S S NS S NS S NS S NS	04420 NS NS S NS S NS S S S S S S S S S S S	500AA20 S NS S S NS S S S NS S S NS S S S S S S S S S S S S S	0EGCG20 NS S NS NS NS NS S NS S NS S NS S S NS S S	500EGCG20 S S NS S S S S S S NS S S NS S S NS S S NS S S NS S S S S S S S S S S S S S	0ns40 NS S NS S NS S NS S NS S S S S S S S S	500ns40 S S S S S S S S S S S S S	0U40 NS S NS S NS S NS S NS S NS S S NS S S	500U40 S S S S NS S S S S S S S S S S S S S	0AA40 NS NS S NS S NS S NS S NS S NS S S NS S S	500A440 S S S S NS S S S S S S S S S S S S S	0EGCG40 NS S NS S NS S S S S S S S S S S S S S	500EGCG40 S S NS NS NS S NS S NS S NS S NS S NS S NS S NS S NS S NS S NS S NS S NS S S NS S S NS S S NS S S NS S S S S S S S S S S S S S
0ms0 500ms0 000 50000 0AA0 500AA0 0EGCG0 500EGCG0 0ms10 500ms10 0U10 500U10 0AA10	0ms20 NS S NS S NS S NS S NS S NS S NS	500ns20 S S S S S S S S S S S S S	0020 NS NS S NS S NS S NS S NS S NS S NS	500U20 S S S S S NS S S NS S NS S NS S S NS S S NS S S S S S S S S S S S S S	04420 NS NS S NS S NS S S S NS S S NS S S NS	500AA20 S S S S S S S S S S S S S	0EGCG20 NS NS NS NS NS NS S NS S NS S NS S NS	500EGCG20 S S NS S NS S S NS S NS S NS S S NS S S NS S S NS S S S S S S S S S S S S S	0ns40 NS NS NS NS S NS S NS S NS S NS S NS	500ns40 S S S S S S S S S S S S S	0040 NS S NS S NS S NS S NS S NS S NS S	500U40 S S S S S S S S S S S S S	0AA40 NS NS S NS S NS S NS S NS S NS S NS	500A40 S S S S S S S S S S S S S	0EGCG40 NS S NS S NS S S S S S S S S S S S S S	500EGCG40 S S NS S NS S NS S NS S NS S NS S NS S NS S NS S NS S NS S S S NS S S NS S S NS S S NS S S NS S S NS S S NS S S S S S NS S S S S NS S S S S S S S S S S S S S
0ns0 500ns0 000 50000 0AA0 5004A0 00500 500600 500ns10 0010 0010 500010 0AA10 500AA10	0ms20 NS S NS S NS S NS S NS S S NS S S S S	500ns20 S S S NS S S S S S S S S S S S S S	01/20 NS S NS S NS S NS S NS S NS S S NS S S	500U20 S S S S S NS S S NS S NS S NS S NS S NS S NS S NS S NS S NS S S NS S S NS S S NS S S NS S S NS S S NS S S S S S S S S S S S S S	04A20 NS S NS S NS S S S S NS S S NS S S S S	500AA20 S S S S S S S S S S S S S	0EGC620 NS NS NS NS NS S S NS S S NS S S S S S	500EGCG20 S NS S NS S S NS S NS S NS S NS S NS S NS S NS S NS S NS S NS S NS S NS S NS S NS S NS S NS S NS S S S NS S S S NS S S S NS S S NS S S NS S S NS S S NS S S S NS S S S S S S S S S S S S S	0ns40 NS NS NS S NS S NS S NS S NS S NS S S S	500ns40 S S S S S S S S S S S S S	0040 NS S NS S NS S NS S NS S NS S NS S	500U40 S S S S S S S S S S S S S	0AA40 NS S NS S NS S NS S NS S NS S NS S S NS S S S	500A440 S S S S S S S S S S S S S	0EGCG40 NS S NS S NS S S S S S NS S S NS S NS	500EGC640 S NS S NS S NS S NS S NS S NS S NS S NS S NS S NS S NS S NS S NS S NS N
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0ns0 500ns0 000 50000 00A0 5004A0 00500 500ns10 0010 500ns10 0010 500010 00A10 500000 500ns20 00120 500ns20 0020 500ns20 5000000 5000000 50000000000000000000	Ons20 NS NS S S NS S S	500ns20	0020 NS S S NS S S NS S S NS S S NS S S NS S S NS S S NS S S S NS S S S NS S S S S S S S S S S S S S	500U20 S S S S S S S S S S S S S	04A20 NS S NS S NS S S NS S NS S NS S NS S	500AA20 S NS S S S S S S S S S S S S S S S	0EGCC20 NS S NS S NS S NS S S NS S S NS S S NS S S NS S S NS S S S S S S S S S S S S S S S S S S S	500EGCG20 S S NS S S S NS S NS S NS S NS S NS S NS S NS S NS S NS S NS S NS S NS S S NS S S S S S S S S S S S S S	0ns40 NS S NS S NS S NS S NS S NS S NS S S NS S S NS S S NS S S NS S S NS S S NS S S NS S S S NS S S S NS S S S NS S S NS S S NS S S S NS S S NS S S NS S S NS S S NS S S S NS S S NS S S NS S S NS S S S NS S S S NS S S S NS S S S S S S S S S S S S S S S S S S S	500ns40 S S S S S S S S S S S S S	0U40 NS S NS S NS S NS S NS S NS S NS S NS	500U40 S S S S S S S S S S S S S	0AA40 NS S NS S S NS S S NS S S S S S S S S	500AA40 S S S S S S S S S S S S S	0EGCC40 NS S NS S NS S S S S S S S NS S S NS S S NS S S S S S S S S S S S S S S S S S S S	500E6CG40 S S NS S S NS S S NS S S NS S S NS S S NS S S NS S S NS S S S NS S NS S NS S NS S NS N
0ns0 500ns0 000 50000 00A0 500A0 500EGCG0 500ns10 500ns10 500L10 00A10 500L10 500EGCG10 500EGCG10 500EGCG10 500EGCG10 500A20 00A20 500A20 500A20 500A20 500A20 500A20 500A20 500A20 500EGCG20 500EGCG20 500EGCG20 500EGCG20	0ns20 NS S NS	500ns20 S S S S S S S S S S S S S S S S S S	0U20 NS S N	500U20 S S S S S S S S S S S S S	04A20 NS S NS	500AA20 S NS S S S S S S S S S S S S S	0EGCC20 NS S NS NS NS NS S NS S NS S NS S NS S NS S NS S NS S NS S NS S NS S NS N	500EGCG20 S S S S S S S S S S S S S	0ns40 NS S NS S NS S NS S NS S NS S NS S NS	500ns40 S S S S S S S S S S S S S	0U40 NS S NS S NS S NS S NS S NS S NS S NS	500140 S S S S S S S S S S S S S	0AA40 NS S NS S NS S NS S NS S S NS S S NS S S NS S S NS S S NS S S S S S S S S S S S S S S S S S S S	500AA40 S S S S S S S S S S S S S	0EGCG40 NS S NS S NS S NS S NS S NS NS S NS NS	500E6CG40 S S NS S NS S NS S NS S NS S NS S NS S NS S NS S NS S NS S NS S NS S NS S NS S NS S S NS S S NS S S NS S S NS S S S NS S S S S S S S S S S S S S
0ns0 500ns0 000 50000 0AA0 500AA0 0EGCG0 500ns10 500ns10 500110 0AA10 500L10 0AA10 500L10 0AA20 500L20 500ns20 0U20 500L20 500A2	0ns20 NS S NS	500ns20	0U20 NS S N	500U20 S S S S S S S S S S S S S S S S S S	04A20 NS S NS	500AA20 S NS S S S S S S S S S S S S S	0EGCC20 NS S NS S NS NS NS NS S NS S NS S NS	500EGC20 S S S S S S S S S S S S S	0ns40 NS S NS	500ns40 S S S S S S S S S S S S S S S S S S	0140 NS S NS S NS S NS S NS S NS S NS S NS	500140 S S S S S S S S S S S S S	0AA40 NS S NS S NS S NS S NS S S NS S S NS S S NS S S NS S S S S S S S S S S S S S S S S S S S	500AA40 S S S S S S S S S S S S S	0EGCG40 NS S NS S NS S NS S NS S NS S NS NS S S NS S S NS S S NS S S S S S S S S S S S S S S S S S S S	500E6CG40 S S NS S NS S NS S NS S NS S NS S NS S NS S NS S NS S NS S NS S S NS S NS S S NS S S NS S S NS S S S NS S S S S S S S S S S S S S
0ns0 500ns0 000 500U0 0AA0 500A0 500EGCG0 500ns10 500ns10 500H10 0AA10 500L10 0AA10 500L10 0AA10 500EGCG10 500EGCG10 500EGCG10 500L20 500A20 500L20 500L20 500L20 500L20 500L20 500EGCG20 500EGCG20 500EGCG20 500EGCG20 500EGCG20	0ns20 NS S NS	500ns20 S S S S S S S S S S S S S S S S S S S	0U20 NS S NS	500U20 S S S S S S S S S S NS S S S S S S S	04A20 NS S NS S NS S NS S S NS S NS S NS S	500AA20 S NS S S S S S S S S S S S S S	0EGCC20 NS S NS NS NS S NS S S NS S S NS S S NS S S S NS S S NS S S S NS S S S S S S S S S S S S S S S S S S S	500EGCG20 S S S S S S S S S S S S S	0ns40 NS S NS	500ns40 S S S S S S S S S S S S S S S S S S S	0140 NS S NS	500140 S S S S S S S S S S S S S	0AA40 NS S NS S NS S NS S S NS S S NS S S NS S S NS S S NS S S S NS S S S S S S S S S S S S S S S S S S S	500AA40 S S S S S S S S S S S S S	0EGCG40 NS S NS S NS S NS S NS S NS NS S NS S	500E6CG40 S S NS S NS S NS S NS S NS S S NS S S NS S S NS S S NS S S S S S S S S S S S S S
0ns0 500ns0 000 500U0 0AA0 500A0 500EGCG0 500EGCG0 0U10 0AA10 500L10 0AA10 500L40 500L40 0ns20 500L20 00A20 500L20 00A20 500L20 00A20 500L20 00A20 500L20 00A20 500L20 00A40 0050 0050 500L20 0050 500L20 0050 500L20 0050 500L20 0050 500L20 0050 500L20 0050 500L20	0ns20 NS S NS	500ns20 S S S S S S S S S S S S S S S S S S S	0U20 NS S N	500U20 S S S S S S S S S S S S S S S S S S	04A20 NS S NS	500AA20 S NS S S S S S S S S S S S S S	0EGCC20 NS S NS S NS S NS S NS S NS S NS S S NS S S NS S S NS S S NS S S NS S S NS S S NS S S NS S S NS S NS S NS S NS S NS S NS N	500EGC220 S S S S S S S S S S S S S	0ns40 NS S NS S NS S NS S NS S	500ns40 S S S S S S S S S S S S S S S S S S S	0140 NS S NS	500040 S S S S S S S S S S S S S	0AA40 NS S NS S NS S NS S S NS S S S S NS S S NS S S NS S S S S S S S S S S S S S S S S S S S	500AA40 S S S S S S S S S S S S S S S S S S	0EGCG40 NS S NS S NS S NS S NS NS NS S NS S N	500E6CG40 S S NS S NS S NS S NS S NS S NS S NS S NS S S NS S S NS S S S S S S S S S S S S S
0ns0 500ns0 000 500U0 0AA0 500EGCG0 500EGCG0 0ns10 500ns10 0A10 500H10 0AA10 500H10 0AA10 500EGCG10 500EGCG10 500ns20 500L20 500L20 500L20 500L20 500L20 500L20 500EGCG20 500EGCG20 500S40 500S40 500S40 500S40 500S40 500S40	0ns20 NS S NS	500ns20 S S S S S S S S S S S S S S S S S S	0120 NS S S NS S S NS S S NS S S NS S S NS S S NS S S NS S S NS S S NS S S NS S S NS S S NS S S NS S S NS S S NS S NS S S S NS S S NS S S S NS S S S NS S S S NS S S S NS S S S NS S S S S S S S S S S S S S	500U20 S S S S S S S NS S S S NS S S S NS S S S S S S S S S S S S S S S S S S S	04A20 NS S NS S NS S S S S NS S S S S S S S S S S S S S S S S S S S	500AA20 S NS S S S NS S S S NS S S S S NS S S S NS S S S S S S S S S S S S S S S S S S S	0EGCG20 NS S NS S NS NS S NS S NS S NS S NS S	500EGCC20 S S S NS S S NS S NS S NS S NS S NS S NS S S NS S S NS S S NS S S NS S S NS S S S S S S S S S S S S S	0ns40 NS S NS	500ns40 S S S S S S S S S S S S S S S S S S S	0140 NS S NS	500U40	0AA40 NS S NS S NS S NS S NS S S S NS S S S S S S S S S S S S S S S S S S S	500AA40 S S S S S S S S S S S S S S S S S S	0EGCC40 NS S NS S NS S S NS S S NS NS S S S NS S S S S S S S S S S S S S S S S S S S	500E6CG40 S S NS S NS S NS S NS S NS S S NS S S NS S S S S S S S S S S S S S
0ns0 500ns0 000 500U0 500U0 500EGCG0 500EGCG0 500EGCG0 00ns10 500ns10 500H10 500H10 500EGCG10 500eS20	0ns20 NS S NS S NS S NS S NS S NS S S NS N	500ns20 S S S S S S S S S S S S S S S S S S	0020 NS S	500U20 S S S S S S S S S S S S S S S S S S	04A20 NS S NS S NS S S NS S S NS S NS S NS	500AA20 S NS S S S S S S S S S S S S S S S S	0EGCC20 NS S NS S NS S S NS S S NS S S NS S S NS S S NS S S NS S S NS S S NS S S NS S S NS S S NS S S NS S S NS S S S NS S S NS S S NS S NS S NS S NS N	500EGC20 S S S S S S S S S S S S S	0ns40 NS S NS	500ns40 S S S S S S S S S S S S S S S S S S S	0140 NS S NS	500U40	0AA40 NS S NS S NS S NS S NS S S S S NS S S S S NS S S S S S S S S S S S S S S S S S S S	500AA40 S S S S S S S S S S S S S S S S S S	0EGCC40 NS S NS S NS S S S NS S S NS NS NS NS S S NS N	500E6CG40 S S NS S NS S NS S NS S NS S NS S NS S S NS S S S S S S S S S S S S S

									0 ho	ur Shape D	ata								
			0ns0			500ns0			010			500T0			000			500G0	
	DF	Count	Conc.	log(Conc.)	Count	Conc. log	(Conc.)	Count	Conc.	og(Conc.)	Count	Conc.	og(Conc.)	Count	Conc.	log(Conc.)	Count	Conc.	og(Conc.)
	3,124	ι,Ω											5						
i	3,125	: மு																	
i	3,125	ហៈ																	
	3,128	ıلم					1												
	15,625	ហៈ			Z	0: 10,937,500;	7.04												
~	15,624	ហ្			ē	0; 15,625,000	7.19												
	15,624	ហ			ස්	5 10,156,250	7.01												
	15,624	ý			7	0; 10,937,500;	7.04												
	78,125	ហ្			3	0: 15,625,000:	7.19				67	52,343,750	7.72				54	42,187,500	7.63
с	78,125	:w			-	3 10,156,250	7.01				64	50,000,000	7.70				52	40,625,000	7.61
0	78,124	ι. Ω			4	5 12,500,000	7.10				62	51,718,750	7.79				09	46,875,000	7.67
•	78.125	ι.Ω			2	1 18.750.000	7.27				73	57.031.250	7.76				59	50.781.250	7.71
	156,250	0				3: 12,500,000	7.10				199	54,687,500	7.74				19	29,687,500	7.47
с	156,250	0				5 9,375,000	6.97				35	54,687,500	7.74				13	20,312,500	7.31
ກ	156,250	0			-4.)	5 7,812,500	6.83				ω	48.437.500	7.69				2	31,250,000	7.49
	156,250	0			2	5 9,375,000	6.97				8	59,375,000	77.7				8	43,750,000	7.64
	312,500	0				1: 12,500,000	7.10				14	43,750,000	7.64				14	43,750,000	7.64
Ę	312,500	0			~	3 25,000,000	7.40				9	56,250,000	7.75				12	37,500,000	7.57
2	312,500	0			*	1 12,500,000	7.10				15	46,875,000	7.67				2	6,250,000;	6.80
	312,500	0				3; 25,000,000;	7.40				17	53,125,000;	7.73				00	25,000,000	7.40
	625,000	0 367	2,293,750,000	9:36		2; 75,000,000	7.88	152	350,000,000	8.98	7	43,750,000	7.64	214	1,337,500,000	9.13	ŝ	31,250,000	7.49
÷	625,000	0	2,381,250,000	35.9		5 37,500,000	7.57	222	1,387,500,000	9.14	0	31,250,000	7.91	209	1,306,250,000	9.12	7	43,750,000	7.64
=	625,000	0 421	2,631,250,000	9.42		3; 56,250,000	7.75	179	1,118,750,000	9.05	60	56,250,000	7.75	228	1,425,000,000	9.15	ιņ	31,250,000	7.49
	625,000	0 434	12,712,500,000	9.43	~	3; 50,000,000;	7.70	204	1,275,000,000	9.11	G	31,250,000	7.49	212	1 ,325,000,000	9.12	œ	50,000,000	7.70
'	1,250,000	0				3; 37, 500,000;	7.57	91	1,137,500,000	90.6	m	37,500,000	7.57	108	1 ,350,000,000	9.13	2	25,000,000	7.40
ć	1,250,000	0			7	4; 50,000,000	7.70	8	1,237,500,000	60.6	2	37,500,000	7.94	8	1,025,000,000	9.01	2		
<u>v</u>	1,250,000	0				1; 12,500,000;	7.10	115	1,437,500,000	9.16	4	50,000,000	7.70	23	287,500,000	8.46	-	12,500,000	7.10
	1,250,000	0				1; 12,500,000;	7.10	94	1,175,000,000	9.07	ï	37,500,000	7.57	54	675,000,000	8.8	'n	37,500,000	7.57
		average	2,504,687,500	9.40	average	22,916,667	7.26	average	1,214,843,750	9.08	average	53,164,063	7.71	average	1,091,406,250	8.99	average	34,169,408	7.49
		stdev	199,110,980	0.035	stdev	18,305,514	0.290	stdev	156,051,213	0.057	stdev	13,276,351	0.104	stdev	407,695,745	0.241	stdev	12,352,214	0.227
		= N	4		=	24		= N	80		= N	20		=	00		= Z	19	

Appendix G

									10 hot	r Shape Da	tta								
			0ns10			500ns10			0T10			500T10			0G10			500G10	
	DF	Count	Conc.	og(Conc.)	Count	Conc.	og(Conc.)	Count	Conc. lo	g(Conc.)	Count	Conc. lo	g(Conc.)	Count	Conc. Ic	og(Conc.)	Count	Conc. lo	g(Conc.)
	3,125																		
۵	3 125															1			
	3.125																		
	15,625					 													
r	15,625																		
<	15,625																		
	15,625																		
	78,125										226 1	76,562,500	8.25				21	16,406,250	7.22
c	78,125										238:1	35,937,500	8.27				- 17	13,281,250	7.12
0	78,125										260 2	13,125,000	8.31				6	39,062,500	7.59
	78,125										228 1	78,125,000	8.25						
	156,250				135	1:217,187,500	8.34	857	1 ,339 ,062 ,500 ;	9.13	8	33,750,000	76.7	236	1 ,150 ,000 ,000 ;	90.6	5	79,687,500	7.90
c	156,250				120	1: 187,500,000	8.27	432	675,000,000	8.8	109:1	70,312,500	8.23	262	1,245,312,500	9.10	24 10	34,375,000	7.93
م	156,250				75	117,187,500	8.07	281	439,062,500	8.64	59	45,312,500	7.66	262	1,243,750,000;	9.09	24	37,500,000	7.57
	156,250				73	114,062,500	8.06	295	460,937,500	8.66	117 1	32,812,500	8.26	616	962,500,000	8.98	19	29,687,500	7.47
	312,500				8	5 296,875,000	8.47	622	1,943,750,000	9.29	12:	37 ,500,000	7.57	435	1 ,359 ,375 ,000	9.13	6	28,125,000	7.45
Ę	312,500				96	1:309,375,000	8.49	86	306,250,000	8.49	34:11	06,250,000	8.03	424	1 ,325 ,000 ,000 ;	9.12	6	28,125,000	7.45
2	312,500				-96	5 296,875,000	8.47	526	1,643,750,000	9.22	37:1	15,625,000	8.06	392	1,225,000,000;	60.6	4	12,500,000	7.10
	312,500				20	1 218,750,000	8.34	311	971,875,000	8.99				496	1,550,000,000;	9.19	31.0	96,875,000	7.99
	625,000	305	1,906,250,000	9.28	16	100,000,000	8.00	301	1,881,250,000	9.27	5	12,500,000	7.10	265	1,656,250,000	9.22	Ö	37,500,000	7.57
÷	625,000	291	1,818,750,000	9.26	15	1:118,750,000	8.07	320	2,000,000,000;	9.30	10:	52,500,000	7.80	245	1,531,250,000	9.19	-	6,250,000	6.80
=	625,000	287	1,793,750,000	9.25	28	3: 175,000,000;	8.24				16:11	000'000'00	8.0	252	1,575,000,000;	9.20		6,250,000	6.80
	625,000				25	5 156,250,000	8.19				9	37,500,000	7.57	242	1,512,500,000	9.18			
	1,250,000	163	2,037,500,000	9.31	2	1 87,500,000	7.94	194	2,425,000,000	9.38		12,500,000	7.10	132	1 ,650 ,000 ,000	9.22	-	12,500,000	7.10
ć	1,250,000	150	1,875,000,000	9.27	2	1 87,500,000	7.94	175	2,187,500,000	9.34	9.1	12,500,000	8.05	133	1 ,662 ,500 ,000	9.22	-	12,500,000	7.10
2	1,250,000	180:	2,250,000,000	9.35	2	1 87,500,000	7.94	185	2,312,500,000	9.36	11	37,500,000	8.14	147	1,837,500,000	9.26	2	25,000,000	7.40
	1,250,000	212	2,650,000,000	9.42	15	162,500,000	8.21	177	2,212,500,000	9.34	8	000'000'00	8.00	137	1,712,500,000	9.23	2	25,000,000	7.40
		average	2,047,321,429	9.31	average	170,800,781	8.19	average	1,485,602,679	9.09 ar	verage 1	08,963,816	7.93	average	1 ,449 ,902 ,344	9.16	average	32,812,500	7.39
	,,	stdev	308,365,507	0.061	stdev	77,740,133	0.195	stdev	770,706,055	0.310 st	dev	52,212,538	0.372	stdev	240,755,152	0.076	stdev	27,136,161	0.351
		=	2		=	16	_	= N	14	z		19		=	16	_	= N	9	

									20 hour S	hape Data									
			0ns20			500ns20		O	T20		ũ	00T20			0G20			500G20	
	DF	Count	Conc. log	1(Conc.)	Count	Conc. log	(Conc.)	Count C	onc. log(C	onc.) C	Count	Conc. lo	g(Conc.)	Count	Conc. lo	g(Conc.)	Count	Conc. Ic	g(Conc.)
	3,125																		
 ۵	3.125			i															
	3,125			:															
	15,625				221	34,531,250	7.54										237	37,031,250	7.57
r-	15,625				241	37,656,250;	7.58										181	28,281,250	7.45
~	15,625				200	31,250,000	7.49										289	45,156,250	7.65
	15,625				245	38,281,250	7.58										202	31,562,500	7.50
	78,125				37	28,906,250	7.46				173 13	5,156,250;	8.13				133:1	03,906,250	8.02
с	78,125				99	43,750,000	7.64				171 13	3,593,750	8.13						
0	78,125				122	95,312,500	7.98				102: 7	9,687,500	7.90						
	78,125				42:	32,812,500	7.52				196: 15	3,125,000	8.19						
[156,250										141 22	0,312,500	8.34				33	50,000,000	7.70
	156,250										151 23	5,937,500	8.37				19	29,687,500	7.47
ກ	156,250										129:20	1,562,500	8.30	·			æ	56,250,000	7.75
	156,250										73:11.	4,062,500	8.06				71:17	10,937,500	8.05
[312,500				73	228,125,000	8.36				63: 19	6,875,000	8.29				31	96,875,000	7.99
ç	312,500				91	284,375,000	8.45				34 10	6,250,000	8.03				20	62,500,000	7.80
2	312,500				47	146,875,000	8.17				73: 22	8,125,000	8.36				œ	25,000,000;	7.40
	312,500				99	206,250,000	8.31			-	68:21.	2,500,000	8.33				23	71,875,000	7.86
[625,000				37	231,250,000	8.36	373; 2, 331	,250,000;	9.37	39:24	3,750,000;	8.39	321 2	006,250,000	9.30	16:1	000'000'000	8.00
Ţ	625,000				8	237,500,000	8.8	367:2,293	750,000	9.36	40 25	000 000 0	8.40	315 1	968,750,000	9.29	6	56,250,000	7.75
=	625,000			_				280: 1,750	000 000	9.24				324 2	025,000,000	9.31			
	625,000							317 1,981	,250,000	9.30				180:1	125,000,000	9.05			
	1,250,000	251	3,137,500,000	9.50	ë	75,000,000	7.88	263; 3,287	200 000	9.52	10:12	5,000,000	8.10	200 2	,500,000,000;	9.40		000'000'000	8.00
ć	1,250,000	2555	3,187,500,000:	9.50	œ	100,000,000;	8.8	213: 2,662	500,000	9.43	49						-	12,500,000	7.10
4	1,250,000	236[2	2,950,000,000	9.47				219 2,737	500,000	9.44									
	1,250,000	228	2,850,000,000	9.45				179 2,237	500,000	9.35							••••		
		average	3,031,250,000	9.48 a	verage	115,742,188	7.92 a	verage 2,410	,156,250	9.37 ave	srage 17.	5,729,167	8.22	average 1	,925,000,000	9.27 av	/erage	59,871,324	7.71
		stdev	158,278,499	0.023 si	tdev	91,706,931	0.376 st	dev 479	570,789	0.085 std	۵، ev	66,000,739	0.156	stdev	497,277,746	0.130 st	dev	31,937,469	0.268
		= Z	4	2	=	16	Z	11	ω	= Z		15	_	= 7	Q	z		17	

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UE Count Cont. Iop[Cont.] Count Cont. Iop[Cont.]	$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$			0ns40			500ns40			0T40			500T40			0G40			500G40	
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1.15 1.25 <th< td=""><td>3.15 3.15</td><td>3,125</td><td>10</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>: :</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></th<>	3.15 3.15	3,125	10								: :									
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$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	$ \begin{bmatrix} 6.525 \\ 1.526 \\ 1$	15,625	5									525	82,031,250	7.91				292	45,625,000	7.66
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	15.625 1.65.25 <th< td=""><td>15,625</td><td>5</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>473</td><td>73,906,250</td><td>7.87</td><td></td><td></td><td></td><td>113:</td><td>17,656,250</td><td>7.25</td></th<>	15,625	5									473	73,906,250	7.87				113:	17,656,250	7.25
$ \begin{bmatrix} 15, 55, 55, 55, 55, 55, 55, 55, 55, 55,$		15,624	5									460	71,875,000	7.86				370	57,812,500	7.76
76 15	78.125 78.125	15,624	5									464	72,500,000	7.86				437	68,281,250	7.83
73125 73125 7325525 73255255 73255255 73255255 $732552555555555555555555555555555555555$	78/15 78/15 78/15 78/15 78/15 79/15 </td <td>78,125</td> <td>2</td> <td></td> <td></td> <td>3</td> <td>22,656,250</td> <td>7.36</td> <td></td> <td></td> <td></td> <td>159</td> <td>24,218,750</td> <td>8.09</td> <td></td> <td></td> <td></td> <td>44</td> <td>34,375,000</td> <td>7.54</td>	78,125	2			3	22,656,250	7.36				159	24,218,750	8.09				44	34,375,000	7.54
7812 7812 $7802, 200$ 740 $7802, 200$ 730 $7302, 200$ $7302, 200$ $7302, 2002, 2002$ $7302, 2002$ $7302, 2002$ $7302, 2002$ $7302, 2002$ $7302, 2002$ $7302, 2002$ $7302, 2002$ $7302, 2002$ $7302, 2002$ $7302, 2002$ $7302, 2002$ $7302, 2002$ $7302, 2002, 2002$ $7302, 2002, 2002$ $7302, 2002, 2002$ $7302, 2002, 2002$	78 78<	78,125	:00			-						8	72,656,250	7.86			:	66	77, 343, 750	7.89
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	78,125	LC I			34	26,562,500	7.42				101	78,906,250	7.90				8	62,500,000	7.80
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	78,124	5			54	42,187,500	7.63			:	247	92,968,750	8.29						
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	155,260 12 16,250 7.2 12 16,250 7.2 12 16,750 7.2 15,	156,250	0			48	75,000,000:	7.88				176	275,000,000	8.44				32	50,000,000	7.70
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	156,250	-			12,	18,750,000	7.27				127	198,437,500	8.30				20	31,250,000	7.49
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312 500 522 1653 125 000 922 163 155 000 933 163 155 000 933 163 155 000 933 163 155 000 933 163 155 000 933 17 13 312 500 231 133 2500 913 231 5500 913 231 5500 923 131 5500 933 131 5500 933 131 5500 933 131 5500 933 131 5500 933 131 5500 933 131 5500 933 131 5500 933 131 55000 933 131 55000 933 131 55000 933 131 55000 131 55000 933 131 55000 933 131 55000 933 131 55000 933 131 55000 933 131 55000 933 131 55000 933 131 55000 933 131 55000 933 131 55000 933 131 55000 933 131 55000 933 131 55000 737 93 55000 737 93 55000 737 93 5000 737 93 5000 737 93 5000 737 93 50000 931 63 75000 93 16	312.500 529 1553 125 000 9 22 153 125 000 9 21 133 125 000 9 13 131 250 000 0 9 13 131 250 000 0 9 13 131 250 000 9 13 111 257 000 00 9 13 131 250 000 0 9 13 131 250 000 0 9 13 131 250 000 0 9 13 131 250 000 0 9 13 131 250 000 0 9 13 131 250 000 0 9 13 131 250 000 0 9 13 131 250 000 0 9 13 131 250 000 0 9 13 131 250 000 0 9 13 131 250 000 0 9 13 131 250 000 0 9 13 131 250 000 0 9 13 131 250 000 0 9 13 131 250 000 0 9 13 131 250	156,250	0			æ	54,687,500	7.74				8	25,000,000	8.10				5	79,687,500	7.90
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	312.500 427 1 334,375,000 913 4601 5000 913 620 1 337,5000 923 7 1 21,5500 7 31 312.500 133 503 1 337,500 913 620 1 37,5500 923 7 21,5500 7 21,5500 7 21,5500 7 21,5500 7 21,55500 7 21,5500 7 21,5500 7 21,55500 7 21,55500 7 21,55500 7 21,55500 7 21,55500 7 21,55500 7 21,55500 7 21,55500 7 21,55500 7 21,5500000 9 21,5500000 9 21,5500000 9 21,15500000 9 21,15500000 9 21,15500000 9 21,15500000 9 21,15500000 9 21,15500000 9 21,15500000 9 21,15500000 9 21,15500000 9 21,15500000 9 21,15500000 9 21,15500000 9 21,15500000 9 21,15500000 9	312,500	0 529	1,653,125,000	9.22				489	528,125,000	9.18	27	84,375,000	7.93	689	2,153,125,000	9.33	14	43,750,000	7.64
312.500123403.125,000861 $426.131,26000$ 9.12 $426.131,26000$ 9.31 2000000 9.33721875,0007.3453.12.5008.2319.46875,0008.14 $525.16005,000$ 9.24 $74.75,000000$ 9.18 80.04 $400.15,0000$ 9.18 $74.55,0000$ $74.55,000000$ 9.17 $74.55,000000$ 9.16 $74.55,000000$ 9.17 $74.55,000000$ 9.17 $74.55,000000$ 9.17 $74.55,000000$ 9.17 $74.55,000000$ 9.17 $74.55,000000$ 9.17 $74.55,000000$ 9.17 $74.55,000000$ 9.12 $74.75,000000$ 9.12 $74.75,000000$ 9.12 $74.75,000000$ 9.12 $74.75,000000$ 9.12 $74.75,000000$ $7.75,000000$ $7.75,000000$ $7.75,000000$ $7.75,000000$ 9.12 $74.75,000000$ 9.12 $74.75,000000$ $7.75,000000$ $7.75,000000$ $7.75,000000$ $7.75,000000$ $7.75,000000$ $7.75,000000$ $7.75,000000$ $7.75,000000$ $7.75,000000$ $7.75,000000$ $7.75,000000$ $7.75,000000$ $7.75,000000$ $7.75,000000$ $7.75,000000$ $7.75,000000$ $7.75,000000$ $7.75,000000$ $7.75,0000000$ $7.75,0000000$ $7.75,0000000$ $7.75,0000000$ $7.75,0000000$ $7.75,0000000$ $7.75,0000000$ $7.75,000000000$ $7.75,00000000000$ $7.75,00000000000000000000000000000000000$	312.500 128 403.125 000 861 451 41 5000 861 77 43 131.250 000 912 912 9375 000 777 6691 2.125 000 000 913 77 45 131.250 007 774 6591 2.000 77 45 131.250 000 774 650 152 130.250 000 123 131.550 000 914 11 10 100 000 914 11 10 100 000 914 11 10 100 000 914 11 10 100 000 914 11 10 100 000 914 11 10 100 000 914 11 11 10 100 000 914 11 11 11 10 100 000 914 11 11 11 11 10 100 000 914 11 11 11 11 10 100 000 914 11 11 11 11 10 100 000 914 11 11 11 11 10 100 000 914 11 11 11 11 10 100 000 914 11 11 11 11 10 100 0000 914 11 11 11 11 11 10 100 0000 914 11 11 11 11 11 11 11 11 11 11 11 11 1	312,500	D 427:	1,334,375,000	9.13				480	200,000,000;	9.18	21	65,625,000	7.82	620	1 ,937 ,500 ,000	9.29	Ö	18,750,000	7.27
312,500 623 1346,575,000 928 743 559 150,000,000 918 92 745 655,000 83 618,750,000 814 745,750,000 764 373 2331,230,000 917 9375,0000 771 655,000 15 337,500,000 797 731,531,531,530,000 927 59,750,000 771 655,000 16 377,500,000 911 175,550,000 911 155,600,000 912 741,550,000 927 770 751 776 771	$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	312,500	J 129:	403,125,000	8.61				426	331,250,000	9.12	19:	59,375,000	77.7	880	2,125,000,000	9.33	7	21,875,000	7.34
655 000 83 518 750 000 871 1 43 750 000 7 43 750 000 931 2 33 750 000 7 37 2 33 750 000 7 37 2 33 750 000 7 37 2 33 750 000 7 37 2 33 750 000 7 37 2 33 750 000 7 37 2 33 750 000 7 37 2 33 750 000 7 37 2 33 750 000 7 37 2 33 750 000 7 37 3 37 50 000 7 37 3 37 50 000 7 37 3 37 50 000 7 37 3 37 50 000 7 37 3 37 50 000 7 37 3 37 50 000 7 37 3 37 50 000 7 37 3 37 50 000 7 37 3 37 50 000 7 37 3 37 50 000 7 37 3 37 50 000 7 37 3 37 50 000 7 37 3 37 50 000 7 37 3 37 50 000 3 37 3 37 50 000 3 37 3 37 50 000 3 37 50 000 3 37 3 37 50 000 3 37 3 37 50 000 3 37 3 37 50 000 3 37 3 37 50 000 3 37 3 37 50 000 3 37 3 37 50 000 3 37 3 37 50 000 3 37 3 37 50 000 3 37 3 37 50 000 3 37 3 37 5	655 000 83 518 750 000 871 1 110 687 500 000 871 231 231 230 200 000 932 85 000 000 737 655 000 121 321 330 200 000 810 373 2 331 250 000 921 131 235 200 000 131 2	312,500	0 623	1,946,875,000	9.29				525	640,625,000	9.22	Ř	09,375,000	8.04	480	1,500,000,000	9.18	6	28,125,000	7.45
625 000 123 785 750 000 819 001 2301 5375 0000 911 131 531 131	655 000 123 768 750 000 8.91 500 105 500 9.11 7.41 7.60 000 9.12 7.61 537 500 000 7.70 537 500 000 7.70 537 500 000 7.70 537 500 000 7.70 537 500 000 7.70 537 500 000 7.70 537 500 000 7.71 7.67	625,000	0	518,750,000	8.71	-			110	687,500,000	8.84	~	43,750,000	7.64	373	2,331,250,000	9.37	8	50,000,000	7.70
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825 000 20 175 000 000 8 10 177 106 250 000 8 23 187 50 000 8 27 19 118 750 000 8 27 19 118 750 000 9 27 19 118 750 000 9 27 10 12 50 000 9 21 11 15 50 000 9 21 11 15 50 000 8 10 11 15 50 000 8 10 11 15 50 0000 9 21 11 15 50 0000 8 10 11 15 50 0000 8 10 12 15 50 0000 12 15 50 00000 12 15 50 00	$ \begin{array}{c} 55500 \\ 250100 \\ 250100 \\ 250100 \\ 260100 \\ 200100 \\ 260100 \\ 200100 \\$	625,000	15.	93,750,000	79.7	-			244	525,000,000	9.18	Ψ	93,750,000	26.7	213	1 ,331 ,250 ,000 ;	9.12	ü	37,500,000	7.57
1,250 000 142 1,775 000 000 9.26 144 1800 0000 9.36 16 200 000 000 8.30 163 2037 500 0000 9.31 112 1500 0000 8.40 163 1237 500 0000 8.40 163 1237 500 0000 8.40 163 1237 500 0000 8.40 1737 500 0000 8.40 1737 500 0000 8.40 1737 500 0000 8.41 275 101 125 00000 8.41 275 101 275 000 000 8.10 175 2.167 00 000 8.10 175 2.167 00 000 8.14 275 2167 500 000 8.14 275 2167 500 000 9.34 275 2167 500 000 8.10 275 2167 500 000 8.10 275 2167 500 000 8.10 275 2167 500 000 8.10 275 2167 500 000 8.10 275 2167 500 000 8.10 275 2167 500 000 8.10 275 2167 500 000 8.10 275 2167 500 000 8.10 275 2167 500 000 8.10 275 2167 500 000 8.10 276	250 142 1775 700 925 144 1800 000 934 142 1775 000 000 931 112 150 100 102 150 100 102 150 100 101 150 100 101 150 100 101 150 100 101 150 100 101 150 100 101 150 100 101 120 100 101 120 100 101 120 100 101 120 100 101 120 100 101 120 100 101 120 100 101 120 100 101 120 100 101 120 100 101 120 100 101 120 100 101 120 100 101 120 100 101 120 100 101 120 100 101 120 100 101 120 101 120 101<	625,000	0 20	125,000,000	8.10	17	106,250,000;	8.03	296	850,000,000;	9.27	19	18,750,000	8.07	298	1,862,500,000	9.27			
1,250,000 29: 322,500,000 8.56 19: 237,500,000 9.41 172:15,000,000 9.41 172:15,000,000 9.41 172:15,000,000 9.41 172:15,000,000 9.41 172:15,000,000 9.41 172:15,000,000 9.41 172:15,000,000 9.41 172:15,000,000 9.41 172:15,000,000 9.41 172:15,000,000 9.41 172:15,000,000 9.41 172:15,000,000 9.41 172:15,000,000 9.41 172:15,000,000 9.41 175:14 9.42 9.41 9.45 9.42 9.41 7.41 9.41 7.41 9.41 9.41 7.41 9.41 7.41 9.41 9.41 7.41 7.41 7.41 7.41 7.41 7.41 7.41 7.41 7.41 7.41 7.41 7.41 7.41 7.41 7.41 7.41	250 000 29 19 27 50 000 8 39 155 237 500 000 9 31 150 187 500 000 9 27 100 175 000 000 9 31 100 175 000 000 9 31 100 175 000 000 9 31 100 175 000 000 9 31 100 175 000 000 9 31 100 175 000 000 9 31 100 175 000 000 9 31 100 175 000 000 9 31 100 175 000 000 9 31 100 175 000 000 9 31 100 175 000 000 9 31 100 175 000 000 9 31 100 175 000 000 9 31 100 175 000 000 9 31 100 175 000 000 9 31 8 31 100 175 000 000 9 31 8 31 100 175 000 000 9 31 8 31 100 175 000 000 9 31 8 31 9 31	1,250,000	D 142;	1 ,775,000,000	9.25	14	175,000,000	8.24	144	300,000,008,1	9.26	16	000'000'000	8.30	163	2,037,500,000	9.31	12	50,000,000	8.18
1,250,000 206: 2,575,000,000 9.41 177: 212,500,000 8.33 154: 1925,000,000 8.14 1925; 000,000 8.14 555 687,500,000 8.84 22 1,250,000 9.41 177: 212,500,000 9.33 154: 1925; 000,000 9.31 191: 237,500,000 8.14 9.55 881,000,000 8.84 107 21,047,500,000 8.04 810,000 8.04 810,000 8.00 800 8.04 800 800 8.00 800 8.00 800 8.00 800 800 8.00 800 8.00 800 8.00 800	250 000 206 (2,575 000 000) 9.41 17/ (2/12) (5/500 000) 8.33 154 (1) (5/2) (5/50 000) 9.23 111 (3/1 (5/10) 000) 8.14 55 687 (500 000) 9.34 22 250 000 0 1 1/2 (2/12) (5/2) (5/0 000) 1/3 (2/12) (5/2) (5/2) (5/0 000) 9.34 1/3 (2/14) (5/12) (5/2) (5/2) (5/0 000) 8.00 250 000 0 1 1/3 (2/14) (5/2)	1,250,000	0 29	362,500,000	8.56	19	237,500,000	8.38	185	2,312,500,000	9.36	20	20,000,000	8.40	150	1 ,875,000,000;	9.27	10:1	25,000,000	8.10
1,250,000 1,252,260,000 8,38 1,751,2,187,500,000 9,34 81,00,000,000 8,30 average 1,050,568,182 8.83 average 16,54,303,000 8,36 1,751,2,187,500,000 9,34 81,00,000,000 8,00 average 1,050,568,182 8.83 average 16,54,013,021 8,04 average 16,75,174 7,68 stdev 83,92,726 0.487 <stdev< td=""> 70,112,87 40,432 0.219 16,87,846 9,76 997 0.204 stdev 10 N= 20,413 0.13 810,419 12,914 446,566 901,419 12,914 166,310,410 17,81 7,68 stdev 10 N= 20,413 0.13 810,419 10,219 10,419 10,117 10,419 10,219 10,419 10,219 10,219 10,214 10,214 10,214 10,214 10,214 10,214 10,214 10,214 10,214 10,214 10,219 10,219 10,214 10,219 10,219</stdev<>	250,000 531 192,337,500,000 931 192,337,500,000 934 81,00,000,000 934 81,00,000,000 934 81,00,000,000 830 175;2,187,500,000 934 81,00,000,000 830 81,00,000,000 830 81,00,000,000 830 81,00,000,000 830 81,00,000,000 830 81,00,000,000 830 81,00,000 830 81,00,000,000 830 81,00,000,000 830 81,00,000 830 81,00,000 830 81,00,000 830 81,00,000 830 81,00,000 830 81,00,000 830 81,00,000 830 81,00,000 830 81,00,000 830 81,00,000 830 81,00,000 830 81,00,000 830 81,00,000 830 81,00,000 830 81,00,000 810 810,00,000 810 810,00,000 810 810,00,000 810 810,00,000 810 810,00,000 810 810,00,000 810 810,00,000 810,00,000 810,00,000 810,00,000 810,00,000 810,00,000 810,00,000<	1,250,000	D 206.	2,575,000,000	9.41	17	212,500,000	8.33	154	,925,000,000	9.28	1	37,500,000	8.14	55	687,500,000	8.84	8		
average 1,050,568,182 8.83 average 1,570,568,182 8.83 average 1,570,568,182 8.24 average 57,715,774 7.86 stdev 843,952,726 0.487 86,740 73 0.132 stdev 66,340,479 0.219 stdev 456,996,680 0.145 stdev 36,088,997 0.274 N = 11 N = 12 N = 12 N = 24 N = 24 N = 21 N = 21 <th< td=""><td>average 1,050,568,182 8.83 average 16,50,568,182 8.83 average 1,050,568,182 8.24 average 57,715,774 7.86 steev 04,395,276 0,487 86,283,073 0,122 steev 66,340,479 0,219 steev 92,4 average 57,715,774 7.86 steev 04,395,776 0,487 64,424,073 0,122 steev 66,340,479 0,219 steev 36,088,997 0,734 7.86 N = 11 N = 79,111,287 0,419 424,424,079 0,122 steev 456,540 124,541ev 36,088,997 0,734 N = 11 N = 24 N = 24 N = 21 21 21</td><td>1,250,000</td><td>0</td><td></td><td></td><td></td><td></td><td></td><td>162</td><td>2,025,000,000</td><td>9.31</td><td>[0]</td><td>237,500,000</td><td>8.3 8</td><td>175</td><td>2,187,500,000</td><td>9.34</td><td></td><td>000 000 000</td><td>8.00</td></th<>	average 1,050,568,182 8.83 average 16,50,568,182 8.83 average 1,050,568,182 8.24 average 57,715,774 7.86 steev 04,395,276 0,487 86,283,073 0,122 steev 66,340,479 0,219 steev 92,4 average 57,715,774 7.86 steev 04,395,776 0,487 64,424,073 0,122 steev 66,340,479 0,219 steev 36,088,997 0,734 7.86 N = 11 N = 79,111,287 0,419 424,424,079 0,122 steev 456,540 124,541ev 36,088,997 0,734 N = 11 N = 24 N = 24 N = 21 21 21	1,250,000	0						162	2,025,000,000	9.31	[0]	237,500,000	8.3 8	175	2,187,500,000	9.34		000 000 000	8.00
stdev 843.952.726 0.487 stdev 79,111,287 0.419 stdev 404,424,073 0.132 stdev 66.340,479 0.219 stdev 36.086,997 36.086	stdev 843,962,726 0.487 stdev 79,111,287 0.419 stdev 404,424,073 0.132 stdev 66,340,479 0.219 stdev 36,086,997 36,086,997 0.274 N = 11 N = 12 N = 12 N = 12 N = 24 N = 12 N = 21		average	1,050,568,182	8.83	average	86,263,021	7.76	average	645,833,333	9.20 a	verage '	125,013,021	8.04 a	verage	1 ,827 ,864 ,583	9.24 a	verage	57,715,774	7.68
N= 11 N= 12 N= 12 N= 24 N= 21 21 S	N= 11 N= 12 N= 12 N= 24 N= 21 21 21 21 21 21 21 21 21 21 21 21 21		stdev	843,962,726	0.487	stdev	79,111,287	0.419	stdev	404,424,073	0.132 s	tdev	66,340,479	0.219 s	tdev	456,956,680	0.145 s	tdev	36,088,997	0.274
			= N	1		= N	12	-	=	12	2	=	24	~	=	12	z		21	



Figure G.01 Size analysis; *E. coli* concentration control groups non-irradiated Blue = 0 hours incubation; Green = 10 hours incubation; Orange = 20 hours incubation; yellow = 40 hours incubation. A sample marked with '*' indicates a significant difference from its control group ($500NS_{-}$).

Appendix H

Shape Significance Chart

	0ns0	500ns0	OTO	500T0	0G0	500G0	0ns10	500ns10	0T10	500T10	0G10	500G10
0ns0		S	NS	S	NS	S	NS	S	NS	S	NS	S
500ns0	S		S	S	S	NS	S	S	S	S	S	NS
OTO	NS	S		S	NS	S	NS	S	NS	S	NS	S
500T0	S	S	S		S	NS	S	S	S	NS	S	NS
0G0	NS	S	NS	S		S	NS	S	NS	S	NS	S
500G0	S	NS	S	NS	S		S	S	S	S	S	NS
Ons10	NS	S	NS	S	NS	S	-	S	NS	S	NS	S
500ns10	S	S	S	S	S	S	S		S	NS	S	S
0T10	NS	S	NS	S	NS	S	NS	S	-	S	NS	S
500T10	S	S	S	NS	S	S	S	NS	S		S	S
0G10	NS	S	NS	S	NS	S	NS	S	NS	S		S
500G10	S	NS	S	NS	S	NS	S	S	S	S	S	
Ons20	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S
500ns20	S	S	S	NS	S	S	S	NS	S	NS	S	S
0T20	NS	S	NS	S	NS	S	NS	S	NS	S	NS	
500T20	S	S	S	S	S	S	S	NS	S	NS	S	S
0G20	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S
500G20	S	S	S	NS	S	NS	S	S	S	NS	S	NS
Ons40	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S
500ns40	S	NS	S	S	S	NS	S	S	S	S	S	NS
0T40	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S
500T40	S	S	S	S	S	S	S	NS	S	NS	S	S
0G40	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S
500G40	S	S	S	NS	S	NS	S	S	S	NS	S	NS
	Ons20	500ns20	0T20	500T20	0G20	500G20	Ons40	500ns40	OT40	500T40	0G40	500G40
0ns0	MC					٥	110	-				
	INO	S	NS	S	NS	S	NS	S	NS	S	NS	S
500ns0	S	S S	NS S	S S	NS S	S S	NS S	S NS	NS S	S S	NS S	S S
500ns0 0T0	S NS	S S S	NS S NS	S S S	NS S NS	S S S	NS S NS	S NS S	NS S NS	S S S	NS S NS	\$ \$ \$
500ns0 0T0 500T0	NS NS S	S S NS	NS S NS S	\$ \$ \$ \$	NS S NS S	S S NS	NS S NS S	S NS S S	NS S NS S	\$ \$ \$ \$	NS S NS S	\$ \$ \$ NS
500ns0 0T0 500T0 0G0	NS NS S NS	S S NS S	NS S NS S NS	\$ \$ \$ \$ \$	NS S NS S NS	S S NS S	NS S NS S NS	S NS S S	NS S NS S NS	\$ \$ \$ \$ \$	NS S NS S NS	S S S NS S
500ns0 0T0 500T0 0G0 500G0	NS NS S NS S	S S NS S S	NS S NS S NS S	\$ \$ \$ \$ \$ \$	NS S NS S NS S	S S NS S NS	NS S NS S NS S	S NS S S NS	NS S NS S NS S	\$ \$ \$ \$ \$ \$	NS S NS S NS S	S S NS S NS
500ns0 0T0 500T0 0G0 500G0 0ns10	NS NS NS S NS	\$ \$ NS \$ \$ \$ \$	NS S NS S NS S NS	S S S S S S S S	NS S NS S NS S NS	S S NS S NS S	NS S NS NS S NS	S NS S S NS S	NS S NS S NS S NS	\$ \$ \$ \$ \$ \$	NS S NS S NS S NS	S S NS S NS S
500ns0 0T0 500T0 0G0 500G0 0ns10 500ns10	NS NS NS S NS S S	S S NS S S S NS	NS S NS S NS S NS S	S S S S S S NS	NS S NS S NS S NS S S	S S NS S NS S S	NS S NS S NS S NS S	S NS S S NS S S	NS S NS S NS S NS S	S S S S S S NS	NS S NS S NS S NS S S	S S NS S NS S S
500ns0 0T0 500T0 0G0 500G0 0ns10 500ns10 0T10	NS NS NS S NS S NS	S S NS S S S NS S S S S S S S S S S	NS S NS	S S S S S S NS S	NS S NS S NS S NS S NS	S S NS S NS S S S S	NS S NS S NS S NS S	\$ NS \$ \$ NS \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$	NS S NS S NS S NS S NS	S S S S S S NS S	NS S NS	\$ \$ NS \$ NS \$ \$ \$ \$ \$ \$
500ns0 0T0 500T0 0G0 500G0 0ns10 500ns10 0T10 500T10	N3 S NS S S S	S S NS S S NS S NS	NS S S S S S	S S S S S NS S NS	NS S NS S NS S NS S S S S	S S NS S NS S S NS	NS S NS S NS S NS S S	\$ NS S NS S S S S S S	NS S S	S S S S S NS S NS	NS S NS S NS S NS S S S S	S S NS S NS S S NS
500ns0 0T0 500T0 0G0 500G0 0ns10 500ns10 0T10 500T10 0G10	N3 S NS	S S NS S	NS S NS S NS S NS S S NS S NS	\$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$	NS S NS S NS S NS S NS S NS	S S NS S NS S S NS S S S S S S	NS S NS S NS S NS S NS S NS	S NS S S NS S S S S S S S	NS S NS S NS S NS S NS S NS	\$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$	NS S NS S NS S NS S NS S NS	S S NS S S S NS S S
500ns0 0T0 500T0 0G0 500G0 0ns10 500ns10 0T10 500T10 0G10 500G10	NS S NS S NS S NS S NS S	\$ \$ NS \$ \$ S NS \$ \$ NS \$ \$ \$ \$ \$ \$ \$ \$ \$	NS S NS S NS S NS S NS S NS	\$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$	NS S NS S NS S NS S NS S S S	S S NS S NS S S NS S S NS S NS	NS S NS S NS S NS S S NS S S	S NS S NS S S S S S NS	NS S NS S NS S NS S S NS S S	\$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$	NS S NS S NS S NS S NS S S NS S	S S NS S S S S NS S S NS
500ns0 0T0 500T0 0G0 500G0 0ns10 500ns10 0T10 500T10 0G10 500G10 0ns20	NS S NS S NS S NS S S S	\$ \$ NS \$ \$ \$ NS \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$	NS S NS S NS S NS S NS NS NS	\$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$	NS S NS S NS S S NS S S NS S S NS	S S NS S S S S S S S S S S S S S S S S	NS S NS S NS S S NS S S S S S	S NS S S S S S S S S S S S S S S NS S S S	NS S NS S NS S S NS S S NS S S NS	S S S S S S S NS S S S S S	NS S NS S NS S NS S NS S NS S NS	S S NS S S S NS S S S S S S S S S S S S
500ns0 0T0 500T0 0G0 500G0 0ns10 500ns10 0T10 500T10 0G10 500G10 0ns20 500ns20	NS S NS S NS S NS S S S S	S S NS S S S NS S S S S S	NS S NS S NS S NS S NS NS NS S S S	S NS	NS S NS S NS S NS S S NS S S NS S S	S S NS S S S S S S S S S S S S S S S S	NS S NS S NS S S S S S S S	S NS S S NS S S S NS S S S S S S S S S	NS S NS S NS S NS S S NS S S NS S S	S S S S S S NS S S S S S S NS	NS S NS S NS S NS S NS S NS S NS S S NS S	S S NS S S S NS S S NS S S NS S S NS
500ns0 0T0 500T0 0G0 500G0 0ns10 500ns10 0T10 500T10 0G10 500C10 0ns20 500ns20 500ns20 0T20	NS S NS S NS S NS S S NS S NS	\$ \$ NS \$ \$ \$ NS \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$	NS S NS S NS S NS S NS NS S S S S	S S	NS S NS S NS S NS S NS S S NS S NS S S NS	S S NS S S S S S S S S S S S S S S S S	NS S NS S NS S NS S S S S S S	S NS S S NS S S S S S S S S S S S S S S	NS S NS S NS S NS S NS S S NS S S NS S S NS	S S S S S S NS S S S S S S S S S S S S	NS S NS S NS S NS S NS S S NS S S NS S S NS	S S NS S S S S NS S NS S S S S S S S S
500ns0 0T0 500T0 0G0 500G0 0ns10 500ns10 0T10 500T10 0G10 500G10 0ns20 500ns20 0T20 500rz0	NS S S NS S S S S S S	S S NS S S S S S S S S S S S S S S S S NS	NS S NS S NS S NS S S NS S S S S S S	S S S S S S S S S S S S S S S S S S S NS S S NS S	NS S NS S NS S NS S NS S S NS S S NS S S S S	S S NS S NS S S NS S NS S S S S S S S	NS S NS S NS S S S S S S S S S S	S NS S NS S NS S	NS S NS S NS S NS S S NS S S NS S S S S	S S S S S S S S S S S S S S S S S S S	NS S NS S NS S NS S NS S NS S S NS S S S S S	S S NS S S S S S S S S S S S S S S S S
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500ns0 0T0 500T0 0G0 500G0 0ns10 500ns10 0T10 500ns10 0G10 500ns10 00ns20 500ns20 0T20 500ns20 0T20 500ns20 500ns20	NS S S NS S S NS S S S	S S NS S S S NS S NS S S S S S S S S S S NS S NS S NS S NS	NS S NS S NS S NS S S S S S S S S S S S	S S S S S S S NS S S NS S NS S NS S NS S S S S S S S S S S	NS S NS S NS S NS S NS S S NS S S S S S	S S NS S NS S S NS S NS S NS S S S S S S S S S S S S S S S	NS S NS S NS S NS S S S S S S S S S S S	S NS S NS S	NS S NS S NS S NS S NS S NS S S NS S S NS S S S S S S S S S S S	S S S S S S NS NS	NS S NS S NS S NS S NS S S NS S S NS S S S S S S	S S NS S S S S NS S S S S S S S S S S S
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500ns0 500T0 500T0 500G0 0ns10 500ns10 0T10 500T10 0G10 500T10 0G20 500T0 500T0 5	NS S S S S S S S S S S S S S S S S S	S S NS S S S S S S S S S S	NS S NS S NS S NS S NS S S S S S S S S	S S S S S S S S NS S S NS S	NS S NS S NS S NS S NS S S S S S S S S	S S NS S NS S NS S NS S NS S NS S S S S S S S S S S S S S S S S S	NS S NS S S NS S S S S S S S S S S S S	S NS S NS S	NS S NS S NS S NS S NS S S NS S S NS S S NS S S S S S S S S S S S S S S	S S S S S S S S S S S S S S S S S S S	NS S NS S NS S NS S NS S NS S NS S S NS S S S	S S NS S S S S S S S S S S S S S S S S
500ns0 0T0 500T0 0G0 500G0 0ns10 500ns10 0T10 500T10 0G10 500T10 0G10 500T20 500T0 500 50	NS S S S NS S S S S S S S S S S S S S S S S S	S S NS S	NS S NS S NS S NS S NS S S S S S S S S	S S	NS S NS S NS S NS S NS S NS S S NS S S NS S S NS S S NS	S S NS S NS S NS S NS S NS S NS S	NS S NS S NS S NS S S S S S S S S S S S S S	S NS S NS S	NS S NS S NS S NS S NS S NS S NS S S NS S S S S S S S S	S S S S S S S S S S S S S S S S S S S	NS S NS	S S S NS
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	15,62%	i0;																	
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	78,12	.(n)			2	1; 16,406,250;	7.22			·	42	32,812,500	7.52				127	99,218,750:	8.8
0	78,129	5.0			2	3; 17,968,750;	7.25				4	35,156,250	7.55				128	100,000,000	8.00
0	78,125	:10			m	6; 28,125,000	7.45				47	36,718,750	7.56				115	89,843,750	7.95
	78,125	:10			2	4: 18,750,000:	7.27				52	19,531,250;	7.29				117	91,406,250;	7.96
	330,624	0				4; 15,625,000;	7.19				2	7,812,500	6.89				26	101,562,500	8.01
c	390,624	LO				8; 31, 250,000	7.49				1	42,968,750	7.63				23	89,843,750	7.95
ກ	390,624	5				6: 23,437,500	7.37				-0	19,531,250	7.29				24:	93,750,000	2.97
	390,624	5				8: 31, 250,000	7.49				12	46,875,000	7.67				25	97,656,250	2.99
	781,250	0				1; 7,812,500;	6.89				-	7,812,500	6.89				13	101,562,500;	8.01
ç	781,250	0				4; 31, 250,000	7.49				e	23,437,500	7.37				14	109,375,000	8.04
2	781,250	0									9	46,875,000	7.67				œ	62,500,000	7.80
	781,250	0				1: 7,812,500;	6.89				чо	39,062,500;	7.59				16	125,000,000;	8.10
	1,562,500	0 93	1,453,125,000	9.16		2 31,250,000	7.49	06	1,406,250,000	9.15	-	15,625,000	7.19	74	1,156,250,000	9.06	1	156,250,000	8.19
÷	1,562,500	0 84	1,312,500,000	9.12				8	1,296,875,000;	9.11	-	15,625,000	7.19	20	1,265,625,000	9.10	4	62,500,000	7.80
=	1,562,500	0 125	1,953,125,000	9.26	_			8	1,343,750,000:	9.13	-	15,625,000	7.19	8	1,375,000,000	9.14	ц	78,125,000	7.89
	1,562,500	0 76:	1,187,500,000	10.6		4		69	1,453,125,000	9.16	-	15,625,000	7.19	98	1,343,750,000	9.13	11	171,875,000	8.24
	3,125,000	0 42	1,312,500,000	9.12				43	1,343,750,000	9.13	2	62,500,000	7.80	DZ	1: 2,187,500,000	9.34	2	62,500,000	7.80
ę	3,125,000	8	1,968,750,000	9.26	_			45	1,406,250,000;	9.15	2	62,500,000	7.80	42	1,312,500,000	9.12	2:	62,500,000	7.80
2	3,125,000	148	1,500,000,000	9.16		1: 31,250,000	7.49	47	1,468,750,000;	9.17	m	93,750,000	7.97	66	1,843,750,000	9.27	۵	187,500,000	8.27
	3,125,000	09	1,562,500,000	9.15				БЕ Е	1,218,750,000	90.6	2	62,500,000	7.80	42	1,312,500,000	9.12	m	93,750,000;	7.97
		average	1,531,250,000	9.16	average	22,475,962	7.31	verage	1 ,367 ,187 ,500	9.14	average	35,117,188	7.45	verage	1 ,474,609,375	9.16 av	/erage	101,835,938	2.99
		stdev	290,641,801	0.080	stdev	8,971,083	0.218 s	stdev	83,519,138	0.027	stdev	22,573,828	0.303	tdev	352,361,443	0.094 st	dev	34,871,632	0.138
		= Z	ω		= N	13	-	=	00		= N	20		-	00	z		20	

Appendix I

	0	log(Conc.)					7.77	7.66	7.64	7.58	7.63	7.55	7.71	77.7	7.85	7.49	7.67	7.37	7.80	7.49	7.67	7.80	7.49	7.49	79.7		7.65	0.150		
	500TTT1	Conc.					ii 58,593,750	1: 45,312,500	43,750,000	1 38,281,250	42,968,750	35,156,250	i 50,781,250	i 58,593,750	1 70,312,500	1 31,250,000	1 46,875,000	1: 23,437,500	Vi 62,500,000	31,250,000	1 46,875,000	1: 62,500,000	31,250,000	31,250,000	1: 93,750,000		47,615,132	17,125,190	<u>5</u>	
		Count					32	ÿ	95	46	1	0)	0	÷	0,	4	U		4	(1)		4	-	-	0		average	stdev	=	
		log(Conc.																	9.19	9.16	9.12	6.00	0.6	70.6	6 6	90.6	9.06	20.0		
	0TTT10	Conc.																	1,562,500,000	3: 1,453,125,000	0.1,390,625,000	1,234,375,000	1,031,250,000	1,093,750,000	0: 1,218,750,000	2 1 ,000 ,000 ,000	1 ,248,046,875	205,164,469	00	
		Count											_			_			00	8	8	22	R	8	R	œ	average	stdev	= N	
	- -	log(Conc.)					7.66	7.56	7.71	7.65	7.7	7.45	7.45	7.45	7.80	7.80	7.67	7.67	7.67	8.1C	7.15	7.85	7.45	7.45	7.80	7.80	7.66	0.192		
	500Trp1(Conc.					1: 45,312,500	35,937,500	50,781,250	1 48,437,500	5 58,593,750	31,250,000	3 31,250,000	3: 31,250,000	1; 62,500,000	62,500,000	6,875,000	6,875,000	3; 46,875,000	3: 125,000,000	15,625,000	5; 78,125,000	31,250,000	31,250,000	000 000 000 000 000 000 000 000 000 00	5 62,500,000	50,234,375	23,289,141	7	
le Data		Count					8	46	59	29	5	ω	w	w			G	۵	(*)	ω	-	40	-	-		2	average	stdev	=	
ur Tripeptid		log(Conc.)																	9.22	9.15	9.13	9.07	9.12	60.6	9.12	9.16	9.13	0.045		
10 hoi	0Trp10	Conc.																	1,640,625,000	1,406,250,000	1,359,375,000	1,171,875,000	1,312,500,000	1,218,750,000	1,312,500,000	1,437,500,000	1,357,421,875	144,764,833	8	
		Count																	105	6	28	52	42	ŝ	42	46	average	stdev	= N	
		log(Conc.)	7.03	7.01	7.04	7.16	7.10	7.15	7.04	6.97	70.7	6.59	6.89	7.19	7.59	6.89	7.19	6.89		7.49							7.08	0.229		
	500ns10	Conc.	9, 10,781,250	5 10,312,500	0 10,937,500	3; 14,531,250	5:12,500,000	3: 14,062,500	4 10,937,500	2; 9,375,000	3 11,718,750	1 3,906,250	2 7,812,500	4: 15,625,000	5 39,062,500	1 7,812,500	2; 15,625,000	1: 7,812,500		2 31,250,000							13,768,382	8,727,280	17	
		:) Count	ũ	ō	71	6	1	1	-	1.								-	g	 ത	0	4	21	0	4	7	5 average	8 stdev	=	
		log(Conc																	0 9.2	0 1.0	0 9.1	0: 9.1.	0.6	0.6	0 9.1	0: 9.2	0 9.1	7 0.06	0	
	0ns10	Conc.																	1,593,750,00	1,546,875,00	1,250,000,00	1,390,625,00	1,187,500,00	1,218,750,00	1,375,000,00	1,875,000,00	1,429,687,50	232,667,39		
		Count																	102	66	8	68	R	R	44	09	average	stdev	= 2	
		DF	15,625	15,625	15 625	15,625	78,125	78.125	78,125	78,125	390,625	390,625	390,625	390,625	781,250	781,250	781,250	781,250	1,562,500	1,562,500	1,562,500	1,562,500	3,125,000	3,125,000	3,125,000	3,125,000				
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7.86 10 78,125,000 7.89 104,152,000 9.21 6,125,000 9.21 6,23,125,000 9.21 6,23,125,000 9.21 6,23,125,000 9.21 6,23,125,000 9.21 6,23,125,000 9.21 6,23,125,000 9.21 6,23,125,000 9.21 6,23,125,000 9.21 6,24 6,24,275,000 9.21 6,14,16,25,000,000 9.21 6,14,16,25,000,000 9.21 6,14,16,25,000,000 9.21 6,14,16,25,000,000 9.21 6,14,16,25,000,000 9.21 6,14,16,25,000,000 9.21 6,14,16,25,000,000 9.21 6,14,16,25,000,000 9.21 6,14,16,25,000,000 9.21 6,14,16,25,000,000 9.21 6,14,16,25,000,000 9.21 6,14,16,25,000,000 9.21 6,14,16,25,000,000 9.21 6,14,16,25,000,000 9.21 6,14,16,25,000,000 9.12 6,14,16,25,000,000 9.21 6,14,16,25,000,000 9.12 10,14,16,25,000,000 9.12 10,14,16,25,000,000 9.12 10,14,16,25,000,000 9.12 10,14,16,25,000,000 9.12 10,14,16,25,000,000 9.12 10,14,16,25,000,000 9.12 1
7.48 103 1,693 375 000 9,21 5,78,125 000 9,21 9,21 7.89 1,201 1,875 000 9,27 11,171 875 000 9,17 7.89 1,201 1,875 000 9,27 11,171 875 000 9,17 7.89 1,201 9,27 11,171 875 000 9,17
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7.80 64,2,000,000,000 9.30 3; 93,750,000 7.97 54,1,687,500,000 9.23
7.97 41 1,261,250,000 9.11 5 156,250,000 8.19 38 1,167,500,000 9.07
7.70 average 1,710,937,500 9.23 average 93,242,188 7.93 average 1,541,015,525 9.18 average
0.196 stdev 229,639,663 0.062 stdev 38,908,640 0.196 stdev 193,169,042 0.066 stdev
N= 8 N= 20 N= 8 N=

	9	log(Conc.)					00 7.49	30 7.51	10 7.54	30: 7.46	30 7.55	0 7.59	7.37	00 7.59	0 6.89	0 6.83	JO: 7.37	10: 7.37	00 7.49	00 7.80		0: 7.19		00: 7.80	0: 7.49	10: 7.49	32 7.44	33 0.244	0	
	500TTT	Conc.					10; 31,250,00	11: 32,031,25	14 34,375,0C	37 28,906,25	9; 35,156,2£	0; 39,062,50	6; 23,437,5C	10; 39,062,50	1: 7,812,5C	1: 7,812,5C	3; 23,437,5L	3 23,437,50	2: 31,250,00	4: 62,500,00		1; 15,625,00		2: 62,500,00	1: 31,250,00	1; 31,250,0C	31,119,75	14,616,46		
		.) Count					ч	ч	ч	0		-		-	7	m	0	0	2	μ	۵	2	4	1	4	۵	2 average	6 stdev	=	
	_	log(Conc													0: 8.9	0.6	0:6	0.8	0: 9.1	0.0	0:6	0; 9.1	0:	0.6	0.8	0	2 9.0	2 0.06	2	
	0TTT40	Conc.													929,687,50	1,070,312,50	1,226,562,50	984,375,00	1,328,125,00	1,109,375,00	1,140,625,00	1,328,125,00	875,000,00	1,031,250,00	875,000,00	906,250,00	1,067,057,29	163,925,75	~	
		Count													119	137:	157:	126	85	71	23	85	28	R	28	29	average	stdev	= N	
	_	log(Conc.)					7.85	7.86	7.88	7.80	7.82	7.89	7.99	7.85	7.85	7.85	7.93	8.12	8.04	8.04	7.89	7.80	7.80	8.19	76.7	7.80	7.91	0.115		
	00Trp40	Conc.					71,093,750	71,875,000	76,562,500	62,500,000	66,406,250	78,125,000	97,656,250	70,312,500	70,312,500	70,312,500	85,937,500	132,812,500	109,375,000	109,375,000	78,125,000	62,500,000	62,500,000	156,250,000	93,750,000	62,500,000	84,414,063	25,475,377	20	
- Data	2	Count					91	92:	86	8	17	2	25	18	6	5	11	17	12	2	'n	4	2:	 10	'n	2	average	stdev	= Z	
ır Tripeptide		log(Conc.)													9.01	<u> 6</u> 6	00.6	8.80	9.09	9.18	60.6	9.11	9.19	9.05	8.99	8.94	9.04	0.107		
40 hot	0Trp40	Conc.													023,437,500	,226,562,500	992,187,500	632,812,500	,218,750,000	500,000,000	,218,750,000	,281,250,000	562,500,000	125,000,000	968,750,000	875,000,000	135,416,667	259,396,677	12	
		Count													131:1	157:1	127	8	78 1	96 1	78:1	82:1	50:1	36.1	31:	28	average 1	stdev	=	
		og(Conc.)	6.86	6.96	6.92	6.89	6.97	6.80	6.67	6.85	6.89	70.7	6.59	70.7	6.89	7.19	6.83		7.19	7.19							6.94 a	0.171 s	~	
	500ns40	Conc.	7,187,500	9,218,750	8,281,250	7,812,500	9,375,000	6,250,000	4,687,500	7,031,250	7,812,500	11,718,750	3,906,250	11,718,750	7,812,500	15,625,000	7,812,500		15,625,000	15,625,000							9,264,706	3,630,403	17	
		Count	46	69	ធា	9	12	ő	ú	5	2	m	-	ň	-	2	-		-	-							average	stdev	=	
		log(Conc.)													1: 9.12	60 ⁻⁶	9.03	9.12	9.08 1	60 [.] 6	90.6	1 9.12	9.13	9.24	00 [.] 6	1 8.97	9.09	0.069		
	0ns40	Conc.													1,320,312,500	1,234,375,000	1,078,125,000	1,328,125,000	1,203,125,000	1,234,375,000	1,125,000,000	1,328,125,000	1,343,750,000	1,718,750,000	000'000'000'1	937,500,000	1,237,630,208	202,672,637	12	
		Count													169:1	158:1	138:1	170	12	. 62	72 1	85	43:1	: 22:	32 1	in the second se	average	stdev	= 2	
		DF	15,625	15,625	15,625	15,625	78,125	78,125	78,125	78,125	390,625	390,625	390,625	390,625	781,250	781,250	781,250	781,250	1,562,500	1,562,500	1,562,500	1,562,500	3,125,000	3,125,000	3,125,000	3,125,000		30		
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Figure I.01 Size analysis; *E. coli* concentration control groups non-irradiated Blue = 0 hours incubation; Green = 10 hours incubation; Orange = 20 hours incubation; yellow = 40 hours incubation. A sample marked with '*' indicates a significant difference from its control group (500NS_).
Appendix J

Tripeptide Significance Chart

	0ns0	500ns0	0Trp0	500Trp0	OTTTO	500TTT0	0ns10	500ns10	0Trp10	500Trp10	OTTT10	500TTT10
0ns0		S	NS	S	NS	S	NS	S	NS	S	NS	S
500ns0	S		S	NS	S	S	S	S	S	S	S	S
0Trp0	NS	S		S	NS	S	NS	S	NS	S	NS	S
500Trp0	S	NS	S		S	S	S	S	S	S	S	S
OTTTO	NS	S	NS	S		S	NS	S	NS	S	NS	S
500TTT0	S	S	S	S	S		S	S	S	S	S	S
Ons10	NS	S	NS	S	NS	S		S	NS	S	NS	S
500ns10	S	S	S	S	S	S	S		S	S	S	S
OTrp10	NS	S	NS	S	NS	S	NS	S		S	NS	S
500Trp10	S	S	S	S	S	S	S	S	S		S	NS
OTTT10	NS	S	NS	S	NS	S	NS	S	NS	S		S
500TTT10	S	S	S	S	S	S	S	S	S	NS	S	
Ons20	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S
500ns20	S	S	S	S	S	S	S	S	S	NS	S	NS
0Trp20	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S
500Trp20	S	S	S	S	S	NS	S	S	S	S	S	S
OTTT20	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S
500TTT20	S	S	S	S	S	NS	S	S	S	S	S	S
Ons40	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S
500ns40	S	S	S	S	S	S	S	NS	S	S	S	S
OTrp40	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S
500Trp40	S	S	S	S	S	NS	S	S	S	S	S	S
OTTT40	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S
500TTT40	S	NS	S	NS	S	S	S	S	S	S	S	S
	0ne20	500nc20	0Trn90	500Trn20	077720	500TTT20	0nc/0	500nc/0	0Trn40	500Tm40	077740	500TTT <i>4</i> 0
(nc)	Ons20	500ns20	OTrp20	500Trp20	OTTT20	500TTT20	Ons40	500ns40	OTrp40	500Trp40	OTTT40	500TTT40
0ns0 500ns0	Ons20 NS	500ns20 S	OTrp20 NS	500Trp20 S	OTTT20 NS S	500TTT20 S	Ons40 NS	500ns40 S	OTrp40 NS	500Trp40 S	OTTT40 NS S	500TTT40 S
0ns0 500ns0 0Trn0	Ons20 NS S	500ns20 S S	OTrp20 NS S	500Trp20 S S S	OTTT20 NS S NS	500TTT20 S S	Ons40 NS S	500ns40 S S	OTrp40 NS S NS	500Trp40 S S S	OTTT40 NS S NS	500TTT40 S NS S
0ns0 500ns0 0Trp0 500Tm0	0ns20 NS S NS S	500ns20 S S S S	OTrp20 NS S NS S	500Trp20 S S S S	OTTT20 NS S NS S	500TTT20 S S S S	Ons40 NS S NS S	500ns40 S S S S	OTrp40 NS S NS S	500Trp40 S S S S	OTTT40 NS S NS S	500TTT40 S NS S NS
0ns0 500ns0 0Trp0 500Trp0 0TTT0	Ons20 NS S NS S NS	500ns20 S S S S S	OTrp20 NS S NS S NS	500Trp20 S S S S S	0TTT20 NS S NS S NS	500TTT20 S S S S S	Ons40 NS S NS S NS	500ns40 S S S S S	0Trp40 NS S NS S NS	500Trp40 S S S S S	OTTT40 NS S NS S NS	500TTT40 S NS S NS S
0ns0 500ns0 0Trp0 500Trp0 0TTT0 500TTT0	0ns20 NS S NS S NS S	500ns20 S S S S S S	0Trp20 NS S NS S NS S	500Trp20 S S S S S NS	0TTT20 NS S NS S NS S	500TTT20 S S S S NS	Ons40 NS S NS S NS S	500ns40 S S S S S S S	0Trp40 NS S NS S NS S	500Trp40 S S S S S NS	0TTT40 NS S NS S NS S	500TTT40 S NS S NS S S
0ns0 500ns0 0Trp0 500Trp0 0TTT0 500TTT0 0ns10	0ns20 NS S NS S NS S NS	500ns20 S S S S S S S S S S S S S S S S S S S	0Trp20 NS S NS S NS S NS	500Trp20 S S S S S NS S	0TTT20 NS S NS S NS S NS	500TTT20 S S S S S NS S	0ns40 NS S NS S NS S NS	500ns40 S S S S S S S S	0Trp40 NS S NS S NS S NS	500Trp40 S S S S S NS S	0TTT40 NS S NS S NS S NS	500TTT40 S NS S NS S S S
0ns0 500ns0 0Trp0 500Trp0 0TTT0 500TTT0 0ns10 500ns10	0ns20 NS S NS S NS S NS S S	500ns20 S S S S S S S S S S S	0Trp20 NS S NS S NS S NS S	500Trp20 S S S S S NS S S S S S S S S S S S S S	0TTT20 NS S NS S NS S NS S S	500TTT20 S S S S NS S S S S	0ns40 NS S NS S NS S NS S	500ns40 S S S S S S S NS	0Trp40 NS S NS S NS S NS S	500Trp40 S S S S S NS S S S	0TTT40 NS S NS S NS S NS S S	500TTT40 S NS S NS S S S S
0ns0 500ns0 0Trp0 500Trp0 0TTT0 500TTT0 0ns10 500ns10 0Trp10	0ns20 NS S NS S NS S NS S NS S NS	500ns20 S S S S S S S S S S S S S	0Trp20 NS S NS S NS S NS S NS	500Trp20 S S S S NS S S S S S S	OTTT20 NS S NS S S NS S NS S NS	500TTT20 S S S S NS S S S S S S	0ns40 NS S NS S NS S NS S NS S NS	500ns40 S S S S S S S NS S	0Trp40 NS S NS S NS S NS S NS	500Trp40 S S S S NS S S S S S S	OTTT40 NS S NS S NS S NS S NS S NS	500TTT40 S NS S S S S S S S S S
0ns0 500ns0 0Trp0 500Trp0 0TTT0 500TTT0 0ns10 500ns10 0Trp10 500rm10	Uns20 NS S NS S NS S NS S NS S NS S	500ns20 S S S S S S S S S NS	0Trp20 NS NS S NS S NS S NS S NS S	500Trp20 S S S S NS S S S S S S S S S S S S S	OTTT20 NS NS S NS S NS S NS S NS S	500TTT20 S S S S S NS S S S S S S S	0ns40 NS NS S NS S NS S NS S NS S	500ns40 S S S S S S NS S S S S S S S S S S S S S	0Trp40 NS NS S NS S NS S NS S NS S	500Trp40 S S S S NS S S S S S S S S S S S S S	OTTT40 NS NS S NS S NS S NS S NS S S	500TTT40 S NS S S S S S S S S S S S
0ns0 500ns0 0Trp0 500Trp0 0TTT0 500TTT0 0ns10 500ns10 0Trp10 500rp10 0TTp10	0ns20 NS S NS S NS S NS S NS S NS S NS	500ns20 S S S S S S S S S NS S	0Trp20 NS S NS S NS S NS S NS S NS S NS	500Trp20 S S S S NS S S S S S S S S S S S S S	OTTT20 NS NS S NS S NS S NS S NS S NS	500TTT20 S S S S S S S S S S S S S	0ns40 NS NS S NS S NS S NS S NS S NS	500ns40 S S S S S S NS S S S S S S S S S S S S S	0Trp40 NS NS S NS S NS S NS S NS S NS	500Trp40 S S S S S S S S S S S S S	OTTT40 NS NS S NS S NS S NS S NS S NS	500TTT40 S NS S S S S S S S S S S S S S
0ns0 500ns0 0Trp0 500Trp0 500Trp0 00TTT0 0ns10 500ns10 0Trp10 500Trp10 500Trp10 500Trp10 500Trp10 500Trp10 500Trp10	0ns20 NS S NS S NS S NS S NS S NS S NS S S S S	500ns20 S S S S S S S S NS S NS	0Trp20 NS S NS S NS S NS S NS S NS S NS S S NS S S S S S S S S S S S S S	500Trp20 S S S S NS S S S S S S S S S S S S S	OTTT20 NS S NS S NS S NS S NS S NS S S S	500TTT20 S S S S S S S S S S S S S	0ns40 NS NS NS S NS S NS S NS S NS S S	500ns40 S S S S S S NS S S S S S S S S S S S S S	0Trp40 NS S NS S NS S NS S NS S NS S S S S S S S S S S S S S	500Trp40 S S S S S NS S S S S S S S S S S S S	0TTT40 NS S NS S NS S NS S NS S NS S S NS S S S S S S S S S S S S S	500TTT40 S NS S S S S S S S S S S S S S
0ns0 500ns0 0Trp0 500Trp0 0TTT0 500TTT0 0ns10 500ns10 0Trp10 500Trp10 500Trp10 500Trp10 0TTT10 500TTT10 0ns20	Ons20 NS S NS S NS S NS S NS S NS S S S S	500ns20 S S S S S S S S NS S NS S S	0Trp20 NS S NS S NS S NS S NS S NS S NS S NS S NS S NS S NS S NS S NS S NS S NS S NS S S NS S S S S S S S S S S S S S	500Trp20	OTTT20 NS S NS	500TTT20 S S S S S S S S S S S S S	Ons40 NS NS S NS S NS S NS S NS S NS S NS	500ns40 S S S S S S S S S S S S S	0Trp40 NS S NS S NS S NS S NS S NS S NS S NS S NS S NS S NS S NS S NS S NS S NS S NS S NS S S NS S S NS S S NS S S S S S S S S S S S S S	500Trp40	0TTT40 NS S S NS S S NS S NS S S NS S S NS S S NS S S NS S S NS S S S NS S S S NS S S NS S S NS S S NS S S NS	500TTT40 S NS S NS S
0ns0 500ns0 0Trp0 500Trp0 0TTT0 500TrT0 0ns10 500ns10 0Trp10 500Tr	Ons20 NS S NS	500ns20 S S S S S S S S NS S NS S S NS S S S S S S S S S S S S S	0Trp20 NS S NS S NS S NS S NS S NS S NS S S NS S S S S S S S S S S S S S	500Trp20 S S S S S S S S S S S S S	0TTT20 NS S NS S NS S NS S NS S NS S NS S S NS S S S S S S S S S S S S S	500TTT20 S S S S S S S S S S S S S	0ns40 NS S NS S NS S NS S NS S NS S NS S S NS S S S S S S S S S S S S S	500ns40 S S S S S S S S S S S S S	0Trp40 NS S NS S NS S NS S NS S NS S NS S S NS S S S S S S S S S S S S S	500Trp40	0TTT40 NS S NS S NS S NS S NS S NS S NS S NS S S NS S S NS S S S S S S S S S S S S S	500TTT40 S NS S NS S S S S S S S S S S S S S S
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0ns0 500ns0 0Trp0 500Trp0 0TTT0 500TTT0 500TT10 500Ts10 0TTp10 500Tp10 0TTT10 500TT10 0ns20 500ns20 0Trp20 500Trp20	0ns20 NS S NS S NS S NS S S NS S S S S S S S	500ns20 S S S S S S S S S NS S S NS S S S S S S S S S S S S S	0Trp20 NS S NS S NS S NS S NS S NS S S S S S S S S S S S S S	500Trp20 S S S S S S S S S S S S S	0TTT20 NS S NS S NS S NS S NS S NS S NS S NS S S NS S S NS S S S S S S S S S S S S S	500TTT20 S S S S S S S S S S S S S	0ns40 NS S NS S NS S NS S NS S NS S NS S NS S NS S S NS S S S S S S S S S S S S S	500ns40 S S S S S S S S S S S S S	0Trp40 NS S NS S NS S NS S NS S NS S NS S NS S NS S S NS S S S S S S S S S S S S S	500Trp40 S S S S S S S S S S S S S	0TTT40 NS S N	500TTT40
0ns0 500ns0 0Trp0 500Trp0 0TTT0 500Tr00 0ns10 500Trp10 500Trp10 0TTT10 500Trp10 500Trp10 500Trp10 500Trp20 500Trp20 0TTT20	0ns20 NS S NS S NS S NS S S S S S S S S S S	500ns20 S S S S S S S S NS S S S S S S S S S S S S S	0Trp20 NS S NS S NS S NS S NS S NS S	500Trp20 S S S S S S S S S S S S S	0TTT20 NS S NS S NS S NS S NS S NS S NS S NS S S NS S S NS S S S S S S S S S S S S S	500TTT20 S S S S S S S S S S S S S	0ns40 NS S NS N	500ns40 S S S S S S S S S S S S S	0Trp40 NS S NS S NS S NS S NS S	500Trp40 S S S S S S S S S S S S S	0TTT40 NS S N	500TTT40 S NS S S S S S S S S S S S S S
0ns0 500ns0 0Trp0 500Trp0 0TTT0 500TTT0 500TT10 500TT10 500TT10 500TTp10 500TTp10 500TTp10 500TTp10 500TTp10 500TTp20 500Trp20 500Trp20 500Trp20 500TTp20 500TTp20	Ons20 NS S	500ns20 S S S S S S S S NS S S S S S S S S S S S S S	0Trp20 NS S NS S NS S NS S NS S NS S	500Trp20 S S S S S S S S S S S S S S S S S S	0TTT20 NS S NS S NS S NS S NS S NS S	500TTT20 S S S S S S S S S S S S S	0ns40 NS S NS S NS S NS S NS S NS S NS S NS S NS S NS S S NS S S NS S S NS S S S S S S S S S S S S S	500ns40 S S S S S S NS S S S S S S S S S S S	0Trp40 NS S NS S NS S NS S NS S	500Trp40	0TTT40 NS S N	500TTT40 S NS S S S S S S S S S S S S S
0ns0 500ns0 0Trp0 500Trp0 0TTT0 500TTT0 500TT10 500ns10 0Trp10 500Trp10 0TT10 500TTp10 00ns20 500Trp20 500Trp20 500Trp20 500Trp20 500Trp20 500Trp20 500Trp20 500Trp20 500Trp20 500Trp20 500Trp20 500Trp20 500Trp20 500Trp20 500Trp20 500Trp20 500Trp20 500Trp20 500Trp10 500Trp20	Ons20 NS S NS	500ns20 S S S S S S S NS S S S S S S S S S S S S S	0Trp20 NS S NS S NS S NS S NS S S NS S NS S NS S NS S NS S NS S NS N	500Trp20 S S S S S S S S S S S S S S S S S S	0TTT20 NS S S NS S S NS N	500TTT20 S S S S S S S S S S S S S	0ns40 NS S NS S NS S NS S NS S NS S NS S NS S NS S NS S S NS S S NS S S NS S S S S S S S S S S S S S	500ns40 S S S S S S NS S S S S S S S S S S S	0Trp40 NS S NS S NS S NS S NS S	500Trp40	0TTT40 NS S N	500TTT40 S NS S S S S S S S S S S S S S
0ns0 500ns0 0Trp0 500Trp0 0TTT0 500TTT0 0ns10 500ns10 0Trp10 500Trp10 00ns20 500Trp10 00ns20 500Trp10 500Trp20 500Trp20	Ons20 NS S	500ns20 S S S S S S S NS S S S S S S S S S S S S S	0Trp20 NS S NS S NS S NS S NS S NS S S S NS S S S NS S S S NS S S S S S S S S S S S S S S S S S S S	500Trp20 S S S S S S S S S S S S S S S S S S	0TTT20 NS S S NS S NS S NS S S NS S S NS S S S NS S S S S S S S S S S S S S S S S S S S	500TTT20 S S S S S S S S S S S S S	0ns40 NS S NS S NS S NS S NS S NS S NS S NS S S NS S S NS S S S S S S S S S S S S S	500ns40 S S S S S S S S S S S S S S S S S S	0Trp40 NS NS S NS S NS S NS S	500Trp40	0TTT40 NS S N	500TTT40 S NS S S S S S S S S S S S S S
0ns0 500ns0 0Trp0 500Trp0 0TTT0 500100 500100 001110 5001010 0100100 5000000 5000000 5000000 5000000 5000000 5000000 50000000 500000000 50000000000 5000000000000000000000000000000000000	Ons20 NS S NS	500ns20 S S S S S S S NS S S S S S S S S S S S S S	0Trp20 NS S NS S NS S NS S NS S S NS S S NS S S NS N	500Trp20 S S S S S S S S S S S S S S S S S S	0TTT20 NS S N	500TTT20 S S S S S S S S S S S S S	0ns40 NS S NS	500ns40 S S S S S S S S S S S S S S S S S S	0Trp40 NS S NS S NS S NS S NS S NS S NS S NS S NS S NS S NS S NS S NS S S NS S S NS S S NS S S NS S S NS S S NS S S NS S S S S S S S S S S S S S	500Trp40 S S S S S S S S S S S S S S S S S S	0TTT40 NS S N	500TTT40 S NS S S S S S S S S S S S S S
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0ns0 500ns0 0Trp0 500Trp0 0TTT0 500TrT0 0ns10 500ns10 0Trp10 500Trp10 500Trp10 0TTT10 0ns20 500Trp20 500Trp20 500Trp20 500Trp20 500Trp20 500Trp20 500Trp20 500Trp20 500Trp20 500Trp20 500Trp20 500Trp20 0ns40 500ns40 0Trp40 500Trp40 500Trp40	Ons20 NS S NS	500ns20 S S S S S S S S S S S S S	0Trp20	500Trp20	OTTT20 NS S NS S NS S NS S NS S NS S S NS S S NS N	500TTT20 S S S S S S S S S S S S S	0ns40 NS S NS	500ns40 S S S S S S S S S S S S S S S S S S	0Trp40 NS S NS S NS S NS S NS S	500Trp40 S S S S S S S S S S S S S S S S S S	0TTT40 NS S N	500TTT40

Appendix K

General Supplies

Table K.01 List of general supplies.

Item	Vendor	Catalog Number	Price
Petri Dishes 100mm x 15mm	Fisher Scientific	08-757-12	\$163.42
20ml Syringe	Becton Dickson	301625	\$31.18
0.2µm Filter	Whatman	91816A	\$50.54
Sterile Loop	Fisher Scientific	13-075-3	\$60.25
Vial with Cap	Fisher Scientific	03-339-21H	\$80.05
250ml Flask	Fisher Scientific	n/a	n/a
1L Bottle	Fisher Scientific	n/a	n/a
Incubator	Fisher Scientific	n/a	n/a
Shaker Incubator	New Brunswick	n/a	n/a
pH Meter	Denver Instrument	n/a	n/a
Irradiation Machine	Isotopes	n/a	n/a
200µl - 1ml Pipette	Biomar	n/a	n/a
50µl - 200µl Pipette	Biomar	n/a	n/a
1ml Pipette Tips	Fisher Scientific	21-197-8F	\$56.10
200µl Pipette Tips	Fisher Scientific	21-197-8G	\$48.45
Bunsen Burner	Fisher Scientific	n/a	n/a

Appendix L

List of Chemicals

Table L.01 List of chemicals.

Item	Vendor	Catalog Number	Price
L-Cysteine	Alfa Aesar	52-90-4	\$20.40
D-Cysteine	MPBio	101438	\$125.40
N-Acetyl-L-Cysteine	Acros	616-91-1	\$37.90
L-Cysteine-Methyl-Ester	Acros	18598-63-5	\$49.00
L-Cysteine-Ethyl-Ester	Acros	868-59-7	\$24.10
Tryptophan	Alfa Aesar	153-94-6	\$22.90
Trp-Trp-Trp	BAChem	H-6970	\$310.00
Uracil	Alfa Aesar	66-22-8	\$10.95
Glutathione	Acros	70-18-8	\$15.40
Epigallocatechin Gallate	Axxora	989-51-5	\$72.00
Ascorbic Acid	Fisher Scientific	50-81-7	\$22.99
Trehalose	Sigma-Aldrich	T5251	\$27.78
Beef Extract	Sigma-Aldrich	B4888-100	\$39.90
Peptone	Fisher Scientific	BP1420-500	\$76.95
Tryptone	Fluka	95039	\$42.30
Yeast Extract	Fluka	70161	\$55.70
Agar	Acros	9002-18-0	\$63.85
Sodium Chloride	Sigma-Aldrich	7647-14-5	\$7.65
Ethanol	Sigma-Aldrich	E7148-1GA	\$33/66

Appendix M



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Chemical Structures

Appendix N

Colony Count Protocol

Original sample concentration (colony forming units per milliliter, CFU/ml) was determined by counting the number of colonies and dividing by the volume of sample originally plated and accounting for the dilution factor. In all cases 100µl was plated and spread with a glass rod. The concentration formula is shown as Equation 1.

$$concentration(CFU / ml) = \frac{plate_count}{100 \mu l} \times \frac{1000 \mu l}{1ml} \times dilution_factor \qquad Equation \ 1.$$

As an example, the plate in Picture XX contains 38 colonies and was plated at a dilution factor of 625,000. The concentration is calculated as:

$$237,500,000(CFU / ml) = \frac{38Colonies}{100\mu l} \times \frac{1000\mu l}{1ml} \times 625,000$$



Picture N.01 Sample plate containing 38 E. coli colonies.

Appendix O

Agar Plate Protocol

Agar plates were prepared using the following recipe:

15.0 g/L Agar10.0 g/L Tryptone5.0 g/L Yeast Extract10 g/L Sodium Chloride

All contents were combined in a one liter autoclavable bottle (Fisher Scientific, St. Louis, MO, USA). The bottle was then filled to volume of one liter with distilled deionized. The pH was adjusted (UB-10, Denver Instrument, Arvada, CO, USA) to 7.0, and the cap was replaced and the contents were gently mixed by bottle inversion. The contents were vented and the cap was left loose for autoclaving. The bottle was autoclaved in a table top pressure vessel (Electric Steroclave, Wisconsin Aluminum Foundry Co., Manitowoc, WI) and was held at 15psi for a minimum of 15 minutes. After the 15 minutes, the vessel was allowed to cool to safely remove the lid. The agar bottles were allowed to cool to a manageable temperature. Once the bottles were cool enough to touch, the agar was poured (using aseptic conditions) into Petri dishes (Fisher Scientific, St. Louis, MO, USA), just enough to cover the bottom of the dish. The dishes were allowed to cool for approximately one hour to allow the agar to completely solidify. At this point the dishes were ready to accept bacterial culture.

Appendix P

Nutrient Broth Protocol

Nutrient Broth was prepared using the following recipe:

3.0 g/L Beef Extract 5 g/L Peptone

All contents were combined in a one liter autoclavable bottle (Fisher Scientific, St. Louis, MO, USA). The bottle was then filled to volume of one liter with distilled deionized. The pH was adjusted (UB-10, Denver Instrument, Arvada, CO, USA) to 7.0, and the cap was replaced and the contents were gently mixed by bottle inversion. The contents were vented and the cap was left loose for autoclaving. The bottle was autoclaved in a table top pressure vessel (Electric Steroclave, Wisconsin Aluminum Foundry Co., Manitowoc, WI) and was held at 15psi for a minimum of 15 minutes. After the 15 minutes, the vessel was allowed to cool to safely remove the lid. The bottles were allowed to continue to room temperature on the bench. Nutrient broth was stored at 4°C while not in use.

Literature Cited

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