

**TEST METHOD PROTOCOL
for the NHK Neutral Red Uptake Cytotoxicity Test**

**A Test for Basal Cytotoxicity for an In Vitro Validation Study
Phase II**

May 15, 2003

Prepared by

**The National Toxicology Program (NTP) Interagency Center for the Evaluation of
Alternative Toxicological Methods (NICEATM)**

**Based on Standard Operating Procedure Recommendations from an
International Workshop Organized by the Interagency Coordinating Committee
on the Validation of Alternative Methods (ICCVAM)**

**National Institute of Environmental Health Sciences (NIEHS)
National Institutes of Health (NIH)
U.S. Public Health Service
Department of Health and Human Services**

TEST METHOD PROTOCOL

The Normal Human Keratinocyte (NHK) Neutral Red Uptake Cytotoxicity Test A Test for Basal Cytotoxicity Phase II

I. PURPOSE

The purpose of this study is to evaluate the cytotoxicity of test chemicals using the Normal Human Keratinocyte (NHK) Neutral Red Uptake (NRU) cytotoxicity test. The data will be used to evaluate the intra- and inter-laboratory reproducibility of the assay and effectiveness of the cytotoxicity assay to predict the starting doses for rodent acute oral systemic toxicity assays. This test method protocol outlines the procedures for performing the cytotoxicity test and is in support of the *in vitro* validation study organized by NICEATM and the European Centre for the Validation of Alternative Methods (ECVAM) and sponsored by NIEHS, U.S. Environmental Protection Agency, and ECVAM. This test method protocol applies to all personnel involved with performing the cytotoxicity assay.

A. NHK Neutral Red Uptake Cytotoxicity Test

The NHK NRU test will be performed to analyze the *in vitro* toxicity of nine (9) blinded/coded test chemicals. This test will be used to determine IC₂₀, IC₅₀, and IC₈₀ values for the predetermined set of test chemicals of varying toxicities.

II. SPONSOR

- A. Name:** National Institute of Environmental Health Sciences (NIEHS); The National Toxicology Program (NTP) Interagency Center for the Evaluation of Alternative Toxicological Methods (NICEATM)
- B. Address:** P.O. Box 12233
Research Triangle Park, NC 27709
- C. Representative:** *Named Representative*

III. IDENTIFICATION OF TEST AND CONTROL SUBSTANCES

- A. Test Chemicals:** *Blinded chemicals (9)*
- B. Controls:**
- | | |
|----------------------|---|
| Positive: | Sodium Lauryl Sulfate |
| Vehicle (Negative): | Assay medium |
| Solvent (as needed): | Assay medium with appropriate solvent used to prepare the test chemicals (Section VII.E) |

IV. TESTING FACILITY AND KEY PERSONNEL

A. Facility Information

- 1) Name:
- 2) Address:
- 3) Study Director:
- 4) Laboratory Technician(s):
- 5) Scientific Advisor:
- 6) Quality Assurance Director:
- 7) Safety Manager:
- 8) Facility Management:

B. Test Schedule

- 1) Proposed Experimental Initiation Date:
- 2) Proposed Experimental Completion Date:
- 3) Proposed Report Date:

V. TEST SYSTEM

The NRU cytotoxicity assay procedure is a cell survival/viability chemosensitivity assay based on the ability of viable cells to incorporate and bind neutral red (NR), a supravital dye. NR is a weak cationic dye that readily penetrates cell membranes by non-ionic diffusion and accumulates intracellularly in lysosomes. Alterations of the cell surface or the sensitive lysosomal membrane lead to lysosomal fragility and other changes that gradually become irreversible. Such changes brought about by the action of xenobiotics result in a decreased uptake and binding of NR. It is thus possible to distinguish between viable, damaged, or dead cells, which is the basis of this assay.

Healthy mammalian cells, when maintained in culture, continuously divide and multiply over time. A toxic chemical, regardless of site or mechanism of action, will interfere with this process and result in a reduction of the growth rate as reflected by cell number. Cytotoxicity is expressed as a concentration dependent reduction of the uptake of the NR after chemical exposure thus providing a sensitive, integrated signal of both cell integrity and growth inhibition.

VI. DEFINITIONS

- A.. Hill function:** a four parameter logistic mathematical model relating the concentration of test chemical to the response being measured in a sigmoidal shape.

$$Y = \text{Bottom} + \frac{\text{Top} - \text{Bottom}}{1 + 10^{(\log \text{IC}_{50} - X) \text{HillSlope}}}$$

where Y= response, X is the logarithm of dose (or concentration), Bottom is the minimum response, Top is the maximum response, logIC₅₀ is logarithm of X at the response midway between Top and Bottom, and HillSlope describes the steepness of the curve.

- B. Documentation:** all methods and procedures will be noted in a Study Workbook; logs will be maintained for general laboratory procedures and equipment (e.g., media preparation, test chemical preparation, incubator function); all optical density data obtained from the

spectrophotometer plate reader will be saved in electronic and paper formats; all calculations of IC_x values and other derived data will be in electronic and paper format; all data will be archived.

VII. PROCEDURES

A. Materials

[Note: Suggested brand names/vendors are listed in parentheses. Equivalents may be used unless otherwise noted.]

1. Cell Lines

Normal Human Epidermal Keratinocytes (NHK)

Non-transformed cells; from cryopreserved primary or secondary cells (**Clonetics #CC-2507 or equivalent**). Cells will be Clonetics NHK cells.

Cambrex [Cambrex Bio Science, 8830 Biggs Ford Road, Walkersville, MD 21793-0127]

Cambrex Europe [Cambrex Bio Science Verviers, S.P.R.L. Parc Industriel de Petit Rechain, B-4800 Verviers, BELGIUM]

2. Technical Equipment

[Note: Suggested brand names/vendors are listed in parentheses. Equivalents may be used.]

- a) Incubator: 37°C ± 1°C, 90 % ± 5 % humidity, 5.0 % ± 1 % CO₂/air
- b) Laminar flow clean bench (standard: "biological hazard")
- c) Water bath: 37°C ± 1°C
- d) Inverse phase contrast microscope
- e) Sterile glass tubes with caps (e.g., 5mL)
- f) Centrifuge (optionally: equipped with microtiter plate rotor)
- g) Laboratory balance
- h) 96-well plate spectrophotometer (i.e., plate reader) equipped with 540 nm ± 10 nm filter
- i) Shaker for microtiter plates
- j) Cell counter or hemocytometer
- k) Pipetting aid
- l) Pipettes, pipettors (multi-channel and single channel; multichannel repeater pipette), dilution block
- m) Cryotubes
- n) Tissue culture flasks (75 - 80 cm², 25 cm²)
- o) 96-well flat bottom tissue culture microtiter plates (e.g., Nunc # 167 008; Corning/COSTAR tissue culture-treated)
- p) pH paper (wide and narrow range)
- q) Multichannel reagent reservoir
- r) Waterbath sonicator
- s) Magnetic stirrer

- t) Antistatic bar ionizer/antistatic gun (optional for neutralizing static on 96-well plates)
- u) Dry heat block (optional)

[Note: Tissue culture flasks and microtiter plates should be prescreened to ensure that they adequately support the growth of NHK. Multi-channel repeater pipettes may be used for plating cells in the 96-well plates, dispensing plate rinse solutions, NR medium, and desorb solution. Do not use the repeater pipette for dispensing test chemicals to the cells.]

3. Chemicals, Media, and Sera

- a) Keratinocyte Basal Medium without Ca^{++} (KBM®, Clonetics CC-3104) that is completed by adding the KBM® SingleQuots® (Clonetics CC-4131) to achieve the proper concentrations of epidermal growth factor, insulin, hydrocortisone, antimicrobial agents, bovine pituitary extract, and calcium (e.g., Clonetics Calcium SingleQuots®, 300 mM CaCl_2 , Clonetics # CC-4202).
- b) HEPES Buffered Saline Solution (HEPES-BSS) (e.g., Clonetics # CC-5022)
- c) 0.025 % Trypsin/EDTA solution (e.g., Clonetics # CC-5012)
- d) Trypsin Neutralizing Solution (TNS) (e.g., Clonetics # CC-5002)
- e) Phosphate Buffered Saline (PBS)
- f) Dulbecco's Phosphate Buffered Saline (D-PBS) [formulation containing calcium and magnesium cations; glucose optional] (for rinsing)
- g) Neutral Red (NR) Dye – tissue culture-grade; liquid form (e.g., SIGMA N 2889); powder form (e.g., SIGMA N 4638)
- h) Dimethyl sulfoxide (DMSO), U.S.P analytical grade (Store under nitrogen @ -20°C)
- i) Ethanol (ETOH), U.S.P. analytical grade (100 %, non-denatured for test chemical preparation; 95 % can be used for the desorb solution)
- j) Glacial acetic acid, analytical grade
- k) Hanks' Balanced Salt Solution without Ca^{2+} or Mg^{2+} (CMF-HBSS) (e.g., Invitrogen # 14170)
- l) Distilled H_2O or any purified water suitable for cell culture (sterile)
- m) Sterile paper towels (for blotting 96-well plates)

B. Preparations of Media and Solutions

[Note: All solutions (except NR stock solution, NR medium and NR desorb), glassware, pipettes, etc., shall be sterile and all procedures should be carried out under aseptic conditions and in the sterile environment of a laminar flow cabinet (biological hazard standard). All methods and procedures will be adequately documented.]

1. Media

- a) Routine Culture Medium/Treatment Medium

KBM® (Clonetics CC-3104) supplemented with KBM® SingleQuots® (Clonetics CC-4131) and Clonetics Calcium SingleQuots® (CC-4202) to make 500 mL medium. Final concentration of supplements in medium are:

0.0001 ng/mL	Human recombinant epidermal growth factor
5 µg/mL	Insulin
0.5 µg/mL	Hydrocortisone

30 µg/mL	Gentamicin
15 ng/mL	Amphotericin B
0.10 mM	Calcium
30 µg/mL	Bovine pituitary extract

Complete media should be kept at 2-8°C and stored for no longer than two weeks.

NOTE:

KBM® SingleQuots® contain the following stock concentrations and volumes:

0.1 ng/mL	hEGF	0.5 mL
5.0 mg/mL	Insulin	0.5 mL
0.5 mg/mL	Hydrocortisone	0.5 mL
30 mg/mL	Gentamicin, 15 µg/mL Amphotericin-B	0.5 mL
7.5 mg/mL	Bovine Pituitary Extract (BPE)	2.0 mL

Clonetics Calcium SingleQuots® are 2 mL of 300mM calcium.

165 µl of solution per 500 mL calcium-free medium equals 0.10 mM calcium in the medium.

2. Neutral Red (NR) Stock Solution

The liquid tissue culture-grade stock NR Solution will be the first choice for performing the assay (e.g., SIGMA #N2889, 3.3 mg/mL). Store liquid tissue culture-grade NR Stock Solution at the storage conditions and shelf-life period recommended by the manufacturer.

If the liquid form is not available, the following formulation can be prepared.

EXAMPLE: 0.33 g NR Dye powder in 100 mL H₂O

The NR Stock Solution (powder in water) should be stored in the dark at room temperature for up to two months.

3. Neutral Red (NR) Medium

EXAMPLE:

1.0 mL (3.3 mg NR dye/mL)	NR Stock Solution
99.0 mL	Routine Culture Medium (pre-warmed to 37° C.)

The final concentration of the NR Medium is **33 µg NR dye/mL** and aliquots will be prepared on the day of application.

[Note: The NR Medium shall be filtered (e.g., Millipore filtering, 0.2 – 0.45 µm pore size) used to reduce NR crystals. Aliquots of the NR Medium should be maintained at 37° C (e.g., in a waterbath) before adding to the cells and used within 30 min of preparation but also used within 15 min after removing from 37° C storage.]

4. Ethanol/Acetic Acid Solution (NR Desorb)

1 %	Glacial acetic acid solution
50 %	Ethanol
49 %	H ₂ O

C. Methods

1. Cell Maintenance and Culture Procedures

NHK cells are routinely grown as a monolayer in tissue culture grade flasks (e.g., 25 cm²) at 37°C ± 1°C, 90 % ± 5 % humidity, and 5.0 % ± 1 % CO₂/air. The cells should be examined on a daily (i.e., on workdays) basis under a phase contrast microscope, and any changes in morphology or their adhesive properties must be noted in a Study Workbook.

2. Receipt of Cryopreserved Keratinocytes

Upon receipt of cryopreserved keratinocytes, the vial(s) of cells shall be stored in a liquid nitrogen freezer until needed.

3. Thawing Cells and Establishing Cell Cultures

- Thaw cells by putting ampules into a water bath at 37°C for as brief a time as possible. Do not thaw cells at room temperature or by hand. Seed the thawed cells into culture flasks as quickly as possible and with minimal handling.
- Slowly (taking approximately 1-2 min) add 9 mL of pre-warmed Routine Culture Medium to the cells suspended in the cryoprotective solution and transfer cells into flasks containing pre-warmed Routine Culture Medium (See Table 1).
- Incubate the cultures at 37°C ± 1°C, 90 % ± 5 % humidity, 5.0 % ± 1 % CO₂/air until the cells attach to the flask (within 4 to 24 h), at which time the Routine Culture Medium should be removed and replaced with fresh Routine Culture Medium.
- Unless otherwise specified, the cells should be incubated at 37°C ± 1°C, 90 % ± 5 % humidity, 5.0 % ± 1 % CO₂/air and fed every 2-3 days until they exceed 50 % confluence (but less than 80 % confluent).

Table 1. Establishing Cell Cultures

Cells/25 cm ² flask (in approximately 5 mL) 1 flask each cell concentration	6.25 x 10 ⁴ (2500/cm ²)	1.25 x 10 ⁵ (5000/cm ²)	2.25 x 10 ⁵ (9000/cm ²)
Approximate Time to Subculture	96+ hours	72 - 96 hours	48 - 72 hours
Cells to 96-Well Plates	6 – 8 plates	6 – 8 plates	6 – 8 plates

Cell growth guidelines – actual growth of individual cell lots may vary.

4. Subculture of NHK Cells to 96-Well Plates

[Note: It is important that cells have overcome the lag growth phase when they are used for the test. Keratinocytes will be passaged only into the 96-well plates and will not be subcultured into flasks for use in later assays]

- a) When the keratinocyte culture in a 25 cm² flask exceeds 50 % confluence (but less than 80 % confluent), remove the medium and rinse the culture twice with 5 mL HEPES-BSS. The first rinse may be left on the cells for up to 5 minutes and the second rinse should remain on the cells for approximately 5 minutes. Discard the washing solutions.
- b) Add 2 mL trypsin/EDTA solution to each flask and remove after 15 to 30 seconds. Incubate the flask at room temperature for 3 to 7 min. When more than 50 % of the cells become dislodged, rap the flask sharply against the palm of the hand.
- c) When most of the cells have become detached from the surface, rinse the flask with 5 mL of room temperature TNS. If more than one flask is subcultured, the same 5 mL of TNS may be used to rinse a total of up to two flasks.
- d) Then rinse the flask with 5 mL CMF-HBSS and transfer the cell suspension to a centrifuge tube.
- e) Pellet the cells by centrifugation for 5 min at approximately 220 x g. Remove the supernatant by aspiration.
- f) Resuspend the keratinocyte pellet by gentle trituration (to have single cells) in Routine Culture Medium. It is important to obtain a single cell suspension for exact counting. Count a sample of the cell suspension using a hemocytometer or cell counter.
- g) Prepare a cell suspension $1.6 - 2.0 \times 10^4$ cells/mL in Routine Culture Medium. Using a multi-channel pipette, dispense 125 μ l Routine Culture Medium only into the peripheral wells (blanks) of a 96-well tissue culture microtiter plate. In the remaining wells, dispense 125 μ l of the cell suspension ($2 \times 10^3 - 2.5 \times 10^3$ cells/well). Prepare one plate per chemical to be tested (see **Figure 2, Section VII.F.1**).
- h) Incubate cells ($37^\circ\text{C} \pm 1^\circ\text{C}$, 90 % \pm 5.0 % humidity, and 5 % \pm 1 % CO₂/air) so that cells form a 20+ % monolayer (~48-72 h). This incubation period assures cell recovery and adherence and progression to exponential growth phase.
- i) Examine each plate under a phase contrast microscope to assure that cell growth is relatively even across the microtiter plate. This check is performed to identify experimental and systemic cell seeding errors. Record observations in the Study Workbook.

5. Determination of Doubling Time

- a) A cell doubling time procedure was performed on the initial lot of cells that was used in the first cell culture assays of Phase Ia of the Validation Study. The doubling time only needs to be determined in Phase II if there is a change in the lot of cells used. Establish cells in culture and trypsinize cells as per **Section VII.C.4** for subculture. Resuspend cells in appropriate culture medium. Use **Table 1** to determine seeding densities.

- b) Seed five sets of cell culture vessels in triplicate for each cell type (e.g., 15 tissue culture dishes [60mm x 15mm]). Use appropriate volume of culture medium for the culture vessels. Note number of cells placed into each culture dish. Place dishes into the incubators ($37^{\circ}\text{C} \pm 1^{\circ}\text{C}$, $90\% \pm 5\%$ humidity, $5.0\% \pm 1\%$ CO_2/air).
- c) After 4-6 hours (use the same initial measurement time for each subsequent doubling time experiment), remove three culture dishes and trypsinize cells. Count cells using a cell counter or hemocytometer. Cell viability may be determined by dye exclusion (e.g., Trypan Blue; Nigrosin). Determine the total number of cells and document. Repeat sampling at 24 hr, 48 hr, 72 hr, and 96 hr post inoculation. Change culture medium at 72 hr or sooner in remaining dishes if indicated by pH drop.
- d) Plot cell concentration (per mL of medium) on a log scale against time on a linear scale. Determine lag time and population doubling time. The doubling time will be in the log (exponential) phase of the growth curve. Additional dishes and time are needed if the entire growth curve is to be determined (lag phase, log phase, plateau phase).

D. Solubility Test

The preference of solvent for dissolving test chemicals is medium, DMSO, and then ethanol. Solubility shall be determined in a step-wise procedure that involves attempting to dissolve a test chemical at a relatively high concentration with the sequence of mechanical procedures specified in **Section VII.D.2.a**. If the chemical does not dissolve, the volume of solvent is increased so as to decrease the concentration by a factor of 10, and then the sequence of mechanical procedures in **Section VII.D.2.a** are repeated in an attempt to solubilize the chemical at the lower concentrations. For testing solubility in media, the starting concentration is 20,000 $\mu\text{g}/\text{mL}$ (i.e., 20 mg/mL) in Tier 1, but for DMSO and ethanol the starting concentration is 200,000 $\mu\text{g}/\text{mL}$ (i.e., 200 mg/mL) in Tier 2. Weighing out chemical for each solvent (i.e., media, DMSO, ethanol) can be done all at once, if convenient, but solubility testing (at each tier that calls for more than one solvent) is designed to be sequential - media, then DMSO, then ethanol – in accordance with the solvent hierarchy (see **Figure 1**). This allows for testing to stop, rather than continue testing with less preferred solvents, if the test chemical dissolves in a more preferred solvent. For example, if a chemical is soluble in medium at a particular tier, testing may stop. Likewise, if a chemical is soluble in DMSO at any tier, testing need not continue with ethanol. However, since the issue of primary importance is testing the solvents and concentrations of test chemical required by any one tier, sequential testing of solvents may be abandoned if the lab can test more efficiently in another way.

1. Determination of Solubility

- a) Tier 1 begins with testing 20 mg/mL in Routine Culture Medium (see **Table 2**). Approximately 10 mg (10,000 μg) of the test chemical will be weighed into a glass tube and the weight will be documented. A volume of Routine Culture Medium, approximately 0.5 mL, will be added to the vessel so that the concentration is 20,000 $\mu\text{g}/\text{mL}$ (20 mg/mL). The solution is mixed as specified in **Section VII.D.2.a**. If complete solubility is achieved in media, then additional solubility procedures are not needed.

- b) If the test chemical is insoluble in medium, proceed to Tier 2 by adding enough medium, approximately 4.5 mL, to attempt to dissolve the chemical at 2 mg/mL by using the sequence of mixing procedures specified in **Section VII.D.2.a**. If the test chemical dissolves in medium at 2 mg/mL, no further procedures are necessary. If the test chemical does NOT dissolve, weigh out approximately 100 mg test chemical in a second glass tube and add enough DMSO to make the total volume approximately 0.5 mL (for 200 mg/mL), and attempt to dissolve the chemical as specified in **Section VII.D.2.a**. If the chemical does not dissolve in DMSO, weigh out approximately 100 mg test chemical in another glass tube and add enough ethanol to make the total volume approximately 0.5 mL (for 200 mg/mL) and attempt to dissolve the chemical as specified in **Section VII.D.2.a**. If the chemical is soluble in either solvent, no additional solubility procedures are needed.
- c) If the chemical is NOT soluble in media, DMSO, or ethanol at Tier 2, then continue to Tier 3 in **Table 2** by adding enough solvent to increase the volume of the three Tier 2 solutions by 10 and attempt to solubilize again using the sequence of mixing procedures in **Section VII.D.2.a**. If the test chemical dissolves, no additional solubility procedures are necessary. If the test chemical does NOT dissolve, continue with Tier 4 and, if necessary, Tier 5 using DMSO and ethanol. Tier 4 begins by diluting the Tier 3 samples with DMSO or ethanol to bring the total volume to 50 mL. The mixing procedures in **Section VII.D.2.a** are again followed to attempt to solubilize the chemical. Tier 5 is performed, if necessary, by weighing out another two more samples of test chemical at ~10 mg each and adding ~50 mL DMSO or ethanol for a 200 µg/mL solution, and following the mixing procedures in **Section VII.D.2.a**.

Example: If complete solubility is not achieved at 20,000 µg/mL in Routine Culture Medium at Tier 1 using the mixing procedures specified in **Section VII.D.2.a**, then the procedure continues to Tier 2 by diluting the solution to 5 mL and mixing again as specified in **Section VII.D.2.a**. If the chemical is not soluble in medium, two samples of ~ 100 mg test chemical are weighed to attempt to solubilize in DMSO and ethanol at 200,000 µg/mL (i.e., 200 mg/mL). Solutions are mixed following the sequence of procedures prescribed in **Section VII.D.2.a** in an attempt to dissolve. If solubility is not achieved at Tier 2, then the solutions (media, DMSO, and ethanol) prepared in Tier 2 are diluted by 10 to test 200 µg/mL in media, and 20,000 µg/mL in DMSO and ethanol. This advances the procedure to Tier 3. Solutions are again mixed as prescribed in **Section VII.D.2.a** in an attempt to dissolve. If solubility is not achieved in Tier 3, the procedure continues to Tier 4, and to 5 if necessary (see **Figure 1** and **Table 2**).

Table 2 Determination of Solubility in Routine Culture Medium, DMSO, or Ethanol

TIER	1	2	3	4	5
Total Volume Medium	0.5 mL	5 mL	50 mL		
Concentration of Test Chemical (Add ~10 mg to a tube. Add enough medium to equal the first volume. Dilute to subsequent volumes if necessary.)	20,000 µg/mL (20 mg/mL)	2,000 µg/mL (2 mg/mL)	200 µg/mL (0.20 mg/mL)		
Total Volume DMSO/Ethanol		0.5 mL	5 mL	50 mL	
Concentration of Test Chemical (Add ~100 mg to a large tube. Add enough DMSO or ethanol to equal the first volume. Dilute to subsequent volumes if necessary.)		200,000 µg/mL (200 mg/mL)	20,000 µg/mL (20 mg/mL)	2,000 µg/mL (2 mg/mL)	
Total Volume DMSO/Ethanol					50 mL
Concentration of Test Chemical (Add ~10 mg to a large tube. Add enough DMSO or ethanol to equal 50 mL.)					200 µg/mL (0.2 mg/mL)
Equivalent Concentration on Cells	10,000 µg/mL (10 mg/mL)	1000 µg/mL (1 mg/mL)	100 µg/mL (0.1 mg/mL)	10 µg/mL (0.01 mg/mL)	1 µg/mL (0.001 mg/mL)

NOTE: The amounts of test chemical weighed and Routine Culture Medium added may be modified from the amounts given above, provided that the targeted concentrations specified for each tier are tested.

Figure 1. Solubility Flow Chart**TIER 1**

STEP 1:	20 mg/mL test chemical (TC) in 0.5 mL medium: <ul style="list-style-type: none"> • if TC soluble, then <u>STOP</u>. • if TC insoluble, then go to STEP 2.
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TIER 2

STEP 2:	2 mg/mL TC in medium – increase volume from STEP 1 by 10 (i.e., to 5 mL) <ul style="list-style-type: none"> • if TC soluble, then <u>STOP</u>. • if TC insoluble, then go to STEP 3.
STEP 3:	200 mg/mL TC in DMSO <ul style="list-style-type: none"> • if TC soluble, then <u>STOP</u>. • if TC insoluble, test at 200 mg/mL in ETOH. <ul style="list-style-type: none"> • if TC soluble, then <u>STOP</u>. • If TC insoluble, go to STEP 4.

TIER 3

STEP 4:	0.2 mg/mL TC in medium – increase volume from STEP 2 by 10 (i.e., to 50 mL) <ul style="list-style-type: none"> • if TC soluble, then <u>STOP</u>. • if TC insoluble, test at 20 mg/mL in DMSO – increase volume from STEP 3 by 10 (i.e., to 5 mL). <ul style="list-style-type: none"> • if TC soluble, then <u>STOP</u>. • if TC insoluble, test at 20 mg/mL in ETOH – increase volume from STEP 3 by 10 (i.e., to 5 mL). <ul style="list-style-type: none"> • if TC soluble, then <u>STOP</u>. • if TC insoluble, then go to STEP 5.
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TIER 4

STEP 5:	2 mg/mL TC in DMSO – increase volume from STEP 4 by 10 (i.e., to 50 mL) <ul style="list-style-type: none"> • if TC soluble, then <u>STOP</u>. • if TC insoluble, test at 2 mg/mL in ETOH – increase volume from STEP 4 by 10 (i.e., to 50 mL). <ul style="list-style-type: none"> • if TC soluble, then <u>STOP</u>. • if TC insoluble, then go to STEP 6.
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TIER 5

STEP 6:	0.2 mg/mL TC in 50 mL DMSO <ul style="list-style-type: none"> • if TC soluble, then <u>STOP</u>. • if TC insoluble, test at 0.2 mg/mL in 50 mL ETOH <ul style="list-style-type: none"> • <u>STOP</u>
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2. Mechanical Procedures

- a) The following hierarchy of mixing procedures will be followed to dissolve the test chemical:
 - 1) Add test chemical to solvent as in Tier 1 of **Table 2**.
 - 2) Gently mix. Vortex the tube (1 –2 minutes).
 - 3) If test chemical hasn't dissolved, use sonication for up to 5 minutes.
 - 4) If sonication doesn't work, then warm solution to 37°C for 5 – 60 minutes. This can be performed by warming tubes in a 37°C water bath or in a CO₂ incubator at 37°C. The solution may be stirred during warming (stirring in a CO₂ incubator will help maintain proper pH).
 - 5) Proceed to Tier 2 (and Tiers 3-5, if necessary of Table 2 and repeat procedures 2-4).
- b) The preference of solvent for dissolving test chemicals is medium, DMSO, and then ethanol. Thus, if a test chemical dissolves in more than one solvent at any one solubility-testing tier, then the choice of solvent follows this hierarchy. For example, if, at any tier, a chemical is soluble in medium and DMSO, but not ethanol, the choice of solvent would be medium. If the chemical were insoluble in medium, but soluble in DMSO and ethanol, the choice of solvent would be DMSO.

After the lab has determined the preferred solvent for the test chemical and before proceeding to the cytotoxicity testing, the Study Director will discuss the solvent selection with the Study Management Team (SMT) of the validation study. The SMT will relate what solvent should be used in the assay for each chemical. If the laboratory has attempted all solubility testing without success, then the SMT will provide additional guidance for achieving test chemical solubility. The SMT anticipates that all validation study test chemicals will be tested in the NRU assays.

E. Preparation of Test Chemicals

[Note: Preparation under red or yellow light is recommended to preserve chemicals that degrade upon exposure to light.]

1. Test Chemical in Solution

- a) Allow test chemicals to equilibrate to room temperature before dissolving and diluting.
- b) Prepare test chemical immediately prior to use. Test chemical solutions should not be prepared in bulk for use in subsequent tests. The solutions must not be cloudy nor have noticeable precipitate. Each stock dilution should have at least 1-2 mL total volume to ensure adequate solution for the test wells in a single 96-well plate. The SMT may direct the Study Director to store an aliquot (e.g., 1 mL) of the highest 2X

stock solution (e.g., low solubility chemicals) in a freezer (e.g., -70°C) for use in future chemical analyses.

- c) For chemicals dissolved in DMSO or ethanol, the final DMSO or ethanol concentration for application to the cells must be 0.5 % (v/v) in the vehicle controls and in all of the eight test concentrations.
- d) The stock solution for each test chemical should be prepared at the highest concentration found to be soluble in the solubility test. Thus, the highest test concentration applied to the cells in each range finding experiment is:
 - 0.5 times the highest concentration found to be soluble in the solubility test, if the chemical was soluble in medium, or
 - 1/200 the highest concentration found to be soluble in the solubility test if the chemical was soluble in ethanol or DMSO.
- e) The seven lower concentrations in the range finding experiment would then be prepared by successive dilutions that decrease by one log unit each. The following example illustrates the preparation of test chemical in solvent and the dilution of dissolved test chemical in medium before application to NHK cells.

Example: Preparation of Test Chemical in Solvent Using a Log Dilution Scheme

If DMSO was determined to be the preferred solvent at Tier 2 of the solubility test (i.e., 200,000 µg/mL), dissolve the chemical in DMSO at 200,000 µg/mL for the chemical stock solution.

- 1) Label eight tubes 1 – 8. Add 0.9 mL solvent (e.g., DMSO) to tubes 2 -- 8.
- 2) Prepare stock solution of 200,000 µg test chemical/mL solvent in tube # 1.
- 3) Add 0.1 mL of 200,000 µg/mL dilution from tube #1 to tube #2 to make a 1:10 dilution in solvent (i.e., 20,000 µg/mL).
- 4) Add 0.1 mL of 20,000 µg/mL dilution from tube #2 to tube #3 to make another 1:10 dilution (i.e., 1:100 dilution from stock solution) in solvent (i.e., 2,000 µg/mL)
- 5) Continuing making serial 1:10 dilutions in the prepared solvent tubes.
- 6) Since each concentration is 200 fold greater than the concentration to be tested, make a 1:100 dilution by diluting 1 part dissolved chemical in each tube with 99 parts of culture medium (e.g., 0.1 mL of test chemical in DMSO + 9.9 mL culture medium) to derive the eight 2X concentrations for application to NHK cells. Each 2X test chemical concentration will then contain 1 % v/v solvent. The NHK cells will have 0.125 mL of culture medium in the wells prior to application of the test chemical. By adding 0.125 mL of the appropriate 2X test chemical concentration to the appropriate wells, the test chemical will be diluted appropriately (e.g., highest concentration in well will be 1,000 µg/mL) in a total of 0.250 mL and the solvent concentration in the wells will be 0.5% v/v.

- 7) A test article prepared in DMSO or ethanol may precipitate upon transfer into the Routine Culture Medium. The 2X dosing solutions should be evaluated for precipitates and the results will be recorded in the workbook. It will be permissible to test all of the dosing solutions in the dose range finding assay only. Doses containing test article precipitates should be avoided, and will not be used in the IC_x determinations for either the range finding experiments or the definitive tests.

Document all test chemical preparations in the Study Workbook.

2. pH of Test Chemical Solutions

Measure the pH of the highest concentration of the test chemical in culture medium using pH paper (e.g., pH 0 – 14 to estimate and pH 5 – 10 to determine more precise value). The pH paper should be in contact with the solution for approximately one minute. Document the pH and note the color of the medium for all dilutions. Do not adjust the pH.

3. Concentrations of Test Chemical

a) Range Finder Experiment

Test eight concentrations of the test chemical by diluting the stock solution with a constant factor covering a large range. The initial dilution series shall be log dilutions (e.g., 1:10, 1:100, 1:1000, etc.).

The data from any well that has precipitate will be excluded from any calculations.

b) Main Experiment

[Note: After the range finding assay is completed, the concentration-response experiment shall be performed three times on three different days for each chemical (i.e., one plate per day per chemical)]

Depending on the slope of the concentration-response curve estimated from the range finder, the dilution/progression factor in the concentration series of the main experiment should be smaller ($\sqrt[6]{10} = 1.47$). Cover the relevant concentration range ($\geq 10\%$ and $\leq 90\%$ effect) preferably with three points of a graded effect, but with a minimum of two points, one on each side of the estimated IC₅₀ value, avoiding too many non-cytotoxic and/or 100 %-cytotoxic concentrations. Experiments revealing less than one cytotoxic concentration on each side of the IC₅₀ value shall be repeated, where possible, with a smaller dilution factor. Each experiment should have at least one cytotoxicity value $\geq 10.0\%$ and $\leq 50.0\%$ viability and at least one cytotoxicity value $> 50.0\%$ and $\leq 90.0\%$ viability. In addition, the dilution scheme shall be adjusted in subsequent replicate assays (i.e., definitive assays), if necessary, to increase the number of points on both sides of the IC₅₀ in the 10-90% response range. (Taking into account pipetting errors, a progression factor of 1.21 is regarded the smallest factor achievable.)

Determine which test chemical concentration is closest to the IC₅₀ value (e.g., 50 % cytotoxicity). Use that value as a central concentration and adjust dilutions higher and lower in equal steps for the definitive assay.

Maximum Doses to be Tested in the Main Experiments

If minimal or no cytotoxicity was measured in the dose range finding assay, a maximum dose for the main experiments will be established as follows:

- For test chemicals prepared in Routine Culture Medium, the highest test article concentration that may be applied to the cells in the main experiments will be either 100 mg/mL, or the maximum soluble dose. Test chemical will be weighed into a glass tube and the weight will be documented. A volume of Routine Culture Medium will be added to the vessel so that the concentration is 200,000 µg/mL (200 mg/mL). The solution is mixed as specified in **Section VII.D.2.a**. If complete solubility is achieved in medium, then 7 additional serial stock dosing solutions may be prepared from the 200 mg/mL 2X stock. If the test chemical is insoluble in medium at 200 mg/mL, proceed by adding medium, in small incremental amounts, to attempt to dissolve the chemical by using the sequence of mixing procedures specified in **Section VII.D.2.a**. The highest soluble stock solution will be used to prepare the 7 additional serial stock dosing solutions.
- For test chemicals prepared in either DMSO or ethanol, the highest test article concentration that may be applied to the cells in the main experiments will be either 2.5 mg/mL, or less, depending upon the maximum solubility in solvent. Test chemical will be weighed into a glass tube and the weight will be documented. A volume of the appropriate solvent (determined from the original solubility test) will be added to the vessel so that the concentration is 500,000 µg/mL (500 mg/mL). The solution is mixed as specified in **Section VII.D.2.a**. If complete solubility is achieved in the solvent, then 7 additional serial stock dosing solutions may be prepared from the 500 mg/mL 200X stock. If the test chemical is insoluble in solvent at 500 mg/mL, proceed by adding solvent, in small incremental amounts, to attempt to dissolve the chemical by using the sequence of mixing procedures specified in **Section VII.D.2.a**. The highest soluble stock solution will be used to prepare the 7 additional serial stock dosing solutions.

c) Test Chemical Dilutions

The dosing factor of 3.16 ($= \sqrt[2]{10}$) divides a log into two equidistant steps, a factor of 2.15 ($= \sqrt[3]{10}$) divides a decade into three steps. The factor of 1.47 ($= \sqrt[6]{10}$) divides a log into six equidistant steps, and the factor of 1.21 ($= \sqrt[12]{10}$) divides the log into 12 steps.

EXAMPLE:

10						31.6						100
10				21.5				46.4				100
10		14.7		21.5		31.6		46.4		68.1		100
10	12.1	14.7	17.8	21.5	26.1	31.6	38.3	46.4	56.2	68.1	82.5	100

The technical production of decimal geometric concentration series is simple. An example is given for factor 1.47:

Dilute 1 volume of the highest concentration by adding 0.47 volumes of diluent. After equilibration, dilute 1 volume of this solution by adding 0.47 volumes of diluent...(etc.).

F. Test Procedure

1. 96-Well Plate Configuration

The NHK NRU assay for test chemicals will use the 96-well plate configuration shown in Figure 2.

Figure 2. 96-Well Plate Configuration for Positive Control and Test Chemical Assays

	1	2	3	4	5	6	7	8	9	10	11	12
A	VCb	VCb	C ₁ b	C ₂ b	C ₃ b	C ₄ b	C ₅ b	C ₆ b	C ₇ b	C ₈ b	VCb	VCb
B	VCb	VC	C ₁	C ₂	C ₃	C ₄	C ₅	C ₆	C ₇	C ₈	VC	VCb
C	VCb	VC	C ₁	C ₂	C ₃	C ₄	C ₅	C ₆	C ₇	C ₈	VC	VCb
D	VCb	VC	C ₁	C ₂	C ₃	C ₄	C ₅	C ₆	C ₇	C ₈	VC	VCb
E	VCb	VC	C ₁	C ₂	C ₃	C ₄	C ₅	C ₆	C ₇	C ₈	VC	VCb
F	VCb	VC	C ₁	C ₂	C ₃	C ₄	C ₅	C ₆	C ₇	C ₈	VC	VCb
G	VCb	VC	C ₁	C ₂	C ₃	C ₄	C ₅	C ₆	C ₇	C ₈	VC	VCb
H	VCb	VCb	C ₁ b	C ₂ b	C ₃ b	C ₄ b	C ₅ b	C ₆ b	C ₇ b	C ₈ b	VCb	VCb

VC = untreated VEHICLE CONTROL (mean viability set to 100 %)
 C₁ – C₈ = Test Chemicals or Positive Control (SLS) at eight concentrations
 (C₁ = highest, C₈ = lowest)
 b = BLANKS (contain **no** cells)
 VCb = VEHICLE CONTROL BLANK

2. Application of Test Chemical

- a) Two optional methods for rapidly applying the 2X dosing solutions onto the 96-well plates may be utilized.
 - 1) The first method is to add each of the 2X dosing solutions into labeled, sterile reservoirs (e.g., Corning/Costar model 4870 sterile polystyrene 50 mL reagent reservoirs or Corning/Transtar model 4878 disposable reservoir liners, 8-channel; or other multichannel reservoirs).

- 2) The second method utilizes a “dummy” plate (i.e., an empty sterile 96-well plate) prepared to hold the dosing solutions immediately prior to treatment of the test plate (with cells). The test chemical and control dosing solutions should be dispensed into the dummy plate in the same pattern/order as will be applied to the plate containing cells. More volume than needed for the test plate (i.e. greater than 125 µl/well) should be in the wells of the dummy plate.

At the time of treatment initiation, a multi-channel micropipettor is used to transfer the 2X dosing solutions, from the reservoirs or dummy plate, to the appropriate wells on the treatment plate (as described in step c. below). These methods will ensure that the dosing solutions can be transferred rapidly to the appropriate wells of the test plate to initiate treatment times and to minimize the range of treatment initiation times across a large number of treatment plates, and to prevent “out of order” dosing. Do not use a multichannel repeater pipette for dispensing test chemical to the plates.

- b) After 48 - 72 h (i.e., after cells attain 20+ % confluency [see Section VII.C.4(h)]) incubation of the cells, add 125 µl of the appropriate concentration of test chemical, the PC, or the VC (see Figure 2 for the plate configuration) directly to the test wells. Do not remove Routine Culture Medium for re-feeding the cells. The dosing solutions will be rapidly transferred from the 8-channel reservoir (or dummy plate) to the test plate using a single delivery multi-channel pipettor. For example, the VC may be transferred first (into columns 1, 2, 11, and 12), followed by the test article dosing solutions from lowest to highest dose, so that the same pipette tips on the multi-channel pipettor can be used for the whole plate. [The Vehicle Control blank (VCb) wells (column 1, column 12, wells A2, A11, H2, H11) will receive the Vehicle Control dosing solutions (which should include any solvents used). Blanks for wells A3 – A10 and H3 – H10 shall receive the appropriate test chemical solution for each concentration (e.g., wells A3 and H3 receive C₁ solution). The test chemical blanks in rows A and H will be used for their respective test chemical concentrations.] Incubate cells for 48 h ± 0.5 h (37°C ± 1°C, 90 % ± 5 % humidity, and 5.0 % ± 1 % CO₂/air).
- c) **Positive Control:** For each set of test chemical plates used in an assay, a separate plate of positive control concentrations will be set up following the concentration range established in the development of the positive control database in Phase I of the Validation Study. If multiple sets of test chemical plates are set up, then clearly designate the positive control plates for each set; each set will be an individual entity. The mean IC₅₀ ± two and a half standard deviations (SD) for the SLS acceptable tests from Phases Ia and Ib (after the removal of outliers) are the values that will be used as an acceptance criterion for test sensitivity for the NHK NRU assay. This plate will follow the same schedule and procedures as used for the test chemical plates (including appropriate chemical concentrations in the appropriate wells – see sections VII.F.1 and F.2)..

3. Microscopic Evaluation

After at least 46 h treatment, examine each plate under a phase contrast microscope to identify systematic cell seeding errors and growth characteristics of control and treated cells. Record any changes in morphology of the cells due to the cytotoxic effects of the test chemical, but do not use these records for any quantitative measure of cytotoxicity. Undesirable growth characteristics of control cells may indicate experimental error and

may be cause for rejection of the assay. Use the following Visual Observations Codes in the description of cell culture conditions.

Visual Observations Codes

Note Code	Note Text
1	Normal Cell Morphology
2	Low Level of Cell Toxicity
3	Moderate Level of Cell Toxicity
4	High level of Cell Toxicity
1P	Normal Cell Morphology with Precipitate
2P	Low Level of Cell Toxicity with Precipitate
3P	Moderate Level of Cell Toxicity with Precipitate
4P	High level of Cell Toxicity with Precipitate
5P	Unable to View Cells Due to Precipitate

4. Measurement of NRU

- a) Carefully remove (i.e., “dump”) the Routine Culture Medium (with test chemical) and rinse the cells very carefully with 250 μ L pre-warmed D-PBS. Remove the rinsing solution by dumping and remove excess by gently blotting on sterile paper towels. Add 250 μ L NR medium (to all wells including the blanks) and incubate ($37^{\circ}\text{C} \pm 1^{\circ}\text{C}$, $90\% \pm 5\%$ humidity, and $5.0\% \pm 1\%$ CO_2/air) for 3 ± 0.1 h. Observe the cells briefly during the NR incubation (e.g., between 2 and 3 h – Study Director’s discretion) for NR crystal formation. Record observations in the Study Workbook. Study Director can decide to reject the experiment if excessive NR crystallization has occurred.
- b) After incubation, remove the NR medium, and carefully rinse cells with 250 μ L pre-warmed D-PBS.
- c) Decant and blot D-PBS from the plate. (Optionally: centrifuge the reversed plate.)
- d) Add exactly 100 μ L NR Desorb (ETOH/acetic acid) solution to all wells, including blanks.
- e) Shake microtiter plate rapidly on a microtiter plate shaker for 20 – 45 min to extract NR from the cells and form a homogeneous solution. Plates should be protected from light by using a cover during shaking.
- f) Plates should be still for at least five minutes after removal from the plate shaker (or orbital mixer). Observe the wells for bubbles. Measure the absorption (within 60 minutes of adding NR Desorb solution) of the resulting colored solution at $540\text{ nm} \pm 10\text{ nm}$ in a microtiter plate reader (spectrophotometer), using the blanks as a reference. [Phases Ia and Ib data show the mean OD value for the plate blanks to be 0.055 ± 0.035 for NHK cells (± 2.5 standard deviations; data from 3 labs; $N = 156$). Use this range as a **guide** for assessment of the blank values.] Save raw data in the Excel format as provided by the SMT.

5. Quality Check of Assay

a) Test Acceptance Criteria

- 1) A test meets acceptance criteria, if the IC_{50} for SLS is within two and a half (2.5) standard deviations of the historical mean established by the Test Facility (as per **VII.F.2.c**).
- 2) A test meets acceptance criteria if the left and the right mean of the VCs do not differ by more than 15.0 % from the mean of all VCs.
- 3) A test meets acceptance criteria if:
 - at least one calculated cytotoxicity value ≥ 10.0 % and ≤ 50.0 % viability and
 - at least one calculated cytotoxicity value > 50.0 % and ≤ 90.0 % viability.
- 4) A test meets acceptance criteria if the r^2 (coefficient of determination) value calculated for the Hill model fit (i.e., from PRISM® software) is ≥ 0.90 . A test does not meet acceptance criteria if the r^2 value is < 0.80 . If the r^2 value is ≥ 0.80 and < 0.90 ("gray zone"), then the SMT will evaluate the model fit and make the determination of whether or not the test meets the acceptance criteria and relate the information to the Study Director.

[Note: All acceptance criteria must be met for an assay to be considered acceptable.]

[A corrected mean $OD_{540 \pm 10nm}$ of 0.205 - 1.645 for the VCs is a target range but will not be a test acceptance criterion. Range determined from Phase Ib VC OD values from 3 laboratories (mean ± 2.5 standard deviations, $N = 69$).]

b) Checks for Systematic Cell Seeding Errors

To check for systematic cell seeding errors, untreated VCs are placed both at the left side (row 2) and the right side (row 11 for the test plates) of the 96-well plate. Aberrations in the cell monolayer for the VCs may reflect a volatile and toxic test article present in the assay.

Checks for cell seeding errors may also be performed by examining each plate under a phase contrast microscope to assure that cell quantity is consistent.

c) Quality Check of Concentration-Response

The IC_{50} derived from the concentration-response of the test chemicals should be backed by preferably three responses ≥ 10 and ≤ 90 % inhibition of NRU and at least two responses, one on either side of the IC_{50} value (see sections **VII.E.3.b** and **VII.F.5.a.3**). If this is not the case, and the concentration progression factor can be easily reduced, reject the experiment and repeat it with a smaller progression factor. In addition, the dilution scheme shall be adjusted in subsequent replicate assays, if necessary, to increase the number of points on both sides of the IC_{50} in the 10-90% response range. Numerical scoring of the cells (see **VII.F.3**) should be determined and documented in the Study Workbook.

G. Data Analysis

A calculation of cell viability expressed as NRU is made for each concentration of the test chemical by using the mean NRU of the six replicate values (minimum of four acceptable replicates wells) per test concentration. The Study Director will use good biological/scientific judgment for determining “unusable” wells that will be excluded from the statistical analysis. This value is compared with the mean NRU of all VC values (provided VC values have met the VC acceptance criteria). Relative cell viability is then expressed as percent of untreated VC. If achievable, the eight concentrations of each chemical tested will span the range of no effect up to total inhibition of cell viability. Data from the microtiter plate reader shall be transferred to the Excel® spreadsheet (template with macros provided by the SMT) that will automatically determine cell viability and perform statistical analyses (including determination of outliers).

The concentration of a test chemical reflecting a 20 %, 50 %, and 80 % inhibition of cell viability (i.e., the IC₂₀, IC₅₀, and IC₈₀) is determined from the concentration-response by applying a Hill function to the concentration-response data. Statistical software (e.g., GraphPad PRISM® 3.0) specified by the SMT shall be used to calculate IC₂₀, IC₅₀, and IC₈₀ values (and the associated confidence limits) for each test chemical. In addition, the SMT shall provide guidelines for calculating IC_x values and confidence limits. The Testing Facility shall report data using at least three (3) significant figures and shall forward the results from each assay to the SMT/biostatistician through the designated contacts in electronic format and hard copy upon completion of testing. The SMT will be directly responsible for the statistical analyses of the Validation Study data.

VIII. REFERENCES

Clonetics Normal Human Keratinocyte Systems Instructions for Use, AA-1000-4-Rev.03/00. (<http://www.clonetics.com>).

Hackenberg, U. and H. Bartling. 1959. Messen und Rechnen im pharmakologischen Laboratorium mit einem speziellen Zahlensystem (WL24-System). Arch. Exp. Pathol. Pharmacol. 235: 437-463.

Triglia, D., P.T. Wegener, J. Harbell, K. Wallace, D. Matheson, and C. Shopsis. 1989. Interlaboratory validation study of the keratinocyte neutral red bioassay from Clonetics Corporation. In *Alternative Methods in Toxicology*, Volume 7. A.M. Goldberg, ed., pp. 357-365. Mary Ann Liebert, Inc., New York.

IX. APPROVAL

SPONSOR REPRESENTATIVE

DATE

(Print or type name)

Testing Facility STUDY DIRECTOR
(Print or type name)

DATE