

(6) Hsie, A.W., Casciano, D.A., Couch, D.B., Krahn, D.F., O'Neill, J.P., Whitfield, B.L. "The use of Chinese hamster ovary cells to quantify specific locus mutation and to determine mutagenicity of chemicals: a report of the U.S. EPA's Gene-Tox Program," *Mutation Research*, 86:193-214 (1981).

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§ 798.5375 In vitro mammalian cytogenetics.

(a) *Purpose.* The in vitro cytogenetics test is a mutagenicity test system for the detection of chromosomal aberrations in cultured mammalian cells. Chromosomal aberrations may be either structural or numerical. However, because cytogenetic assays are usually designed to analyse cells at their first post-treatment mitosis and numerical aberrations require at least one cell division to be visualized, this type of aberration is generally not observed in a routine cytogenetics assay. Structural aberrations may be of two types, chromosome or chromatid.

(b) *Definitions.* (1) Chromosome-type aberrations are changes which result from damage expressed in both sister chromatids at the same time.

(2) Chromatid-type aberrations are damage expressed as breakage of single chromatids or breakage and/or reunion between chromatids.

(c) *Reference substances.* Not applicable.

(d) *Test method—(1) Principle.* In vitro cytogenetics assays may employ cultures of established cell lines, cell strains or primary cell cultures. Cell cultures are exposed to the test substance both with and without metabolic activation. Following exposure of cell cultures to test substances, they are treated with a spindle inhibitor (e.g., colchicine or Colcemid#) to arrest cells in a metaphase-like stage of mitosis (c-metaphase). Cells are then harvested and chromosome preparations made. Preparations are stained and metaphase cells are analyzed for chromosomal aberrations.

(2) *Description.* Cell cultures are exposed to test compounds and harvested at various intervals after treatment. Prior to harvesting, cells are treated with a spindle inhibitor (e.g., col-

chicine or Colcemid#) to accumulate cells in c-metaphase. Chromosome preparations from cells are made, stained and scored for chromosomal aberrations.

(3) *Cells—(i) Type of cells used in the assay.* There are a variety of cell lines or primary cell cultures, including human cells, which may be used in the assay. Established cell lines and strains should be checked for *Mycoplasma* contamination and may be periodically checked for karyotype stability.

(ii) *Cell growth and maintenance.* Appropriate culture media, and incubation conditions (culture vessels CO₂ concentrations, temperature and humidity) shall be used.

(4) *Metabolic activation.* Cells shall be exposed to test substance both in the presence and absence of an appropriate metabolic activation system.

(5) *Control groups.* Positive and negative (untreated and/or vehicle) controls both with and without metabolic activation shall be included in each experiment. When metabolic activation is used, the positive control substance shall be known to require such activation.

(6) *Test chemicals—(i) Vehicle.* Test substances may be prepared in culture media or dissolved or suspended in appropriate vehicles prior to treatment of the cells. Final concentration of the vehicle shall not interfere with cell viability or growth rate. Treatment vessels should be chosen to ensure that there is no visible interaction, such as etching, between the solvent, the test chemical, and the vessel.

(ii) *Exposure concentrations.* Multiple concentrations of the test substance over a range adequate to define the response should be tested. Generally the highest test substance concentrations tested with and without metabolic activation should show evidence of cytotoxicity or reduced mitotic activity. Relatively insoluble substances should be tested up to the limit of solubility. For freely soluble nontoxic chemicals, the upper test chemical concentration should be determined on a case by case basis.

(e) *Test performance—(1) Established cell lines and strains.* Prior to use in the assay, cells should be generated from

stock cultures, seeded in culture vessels at the appropriate density and incubated at 37 °C.

(2) *Human lymphocyte cultures.* Heparinized or acid-citrate-dextrose whole blood should be added to culture medium containing a mitogen, e.g., phytohemagglutinin (PHA) and incubated at 37 °C. White cells sedimented by gravity (buffy coat) or lymphocytes which have been purified on a density gradient may also be utilized.

(3) *Treatment with test substance.* For established cell lines and strains, cells in the exponential phase of growth shall be treated with test substances in the presence and absence of an exogenous metabolic activation system. Mitogen-stimulated human lymphocyte cultures may be treated with the test substance in a similar manner.

(4) *Number of cultures.* At least two independent cultures shall be used for each experimental point.

(5) *Culture harvest time.* (i) For established cell lines and strains, multiple harvest times are recommended. However, for screening purposes, a single harvest time may be appropriate. If the test chemical changes the cell cycle length, the fixation intervals should be changed accordingly. If a single harvest time is selected, supporting data for the harvest time should be presented in such a study.

(ii) For human lymphocyte cultures, the substance to be tested may be added to the cultures at various times after mitogen stimulation so that there is a single harvest time after the initiation of the cell culture. Alternatively, a single treatment may be followed by multiple harvest times. Harvest time should be extended for those chemicals which induce an apparent cell cycle delay. Because the population of human lymphocytes is only partially synchronized, a single treatment, at, or close to, the time when metaphase stages first appear in the culture will include cells in all phases of the division cycle. Therefore, a single harvest at the time of second mitosis may be carried out for screening purposes.

(iii) Cell cultures shall be treated with a spindle inhibitor, (e.g., colchicine or Colcemid®), 1 or 2 hours prior to harvesting. Each culture shall

be harvested and processed separately for the preparation of chromosomes.

(6) *Chromosome preparation.* Chromosome preparation involves hypotonic treatment of the cells, fixation and staining.

(7) *Analysis.* Slides shall be coded before analysis. In human lymphocytes, only cells containing 46 centromeres shall be analyzed. In established cell lines and strains, only metaphases containing ± 2 centromeres of the modal number shall be analyzed. Uniform criteria for scoring aberrations shall be used.

(8) *Confirmatory tests.* When appropriate, a single positive response shall be confirmed by testing over a narrow range of concentrations.

(f) *Data and report—(1) Treatment of results.* Data shall be presented in a tabular form. Different types of structural chromosomal aberrations shall be listed with their numbers and frequencies for experimental and control groups. Data should be evaluated by appropriate statistical methods. Gaps or achromatic lesions are recorded separately and not included in the total aberration frequency.

(2) *Statistical evaluation.* Data should be evaluated by appropriate statistical methods.

(3) *Interpretation of results.* (i) There are several criteria for determining a positive result, one of which is a statistically significant dose-related increase in the number of structural chromosomal aberrations. Another criterion may be based upon detection of a reproducible and statistically significant positive response for at least one of the test substance concentrations.

(ii) A test substance which does not produce either a statistically significant dose-related increase in the number of structural chromosomal aberrations or a statistically significant and reproducible positive response at any one of the test points is considered nonmutagenic in this system.

(iii) Both biological and statistical significance should be considered together in the evaluation.

(4) *Test evaluation.* (i) Positive results in the in vitro cytogenetics assay indicate that under the test conditions the test substance induces chromosomal

aberrations in cultured mammalian somatic cells.

(ii) Negative results indicate that under the test conditions the test substance does not induce chromosomal aberrations in cultured mammalian somatic cells.

(5) *Test report.* In addition to the reporting recommendations as specified under 40 CFR part 792, subpart J the following specific information shall be reported:

(i) Cells used, density and passage number at time of treatment, number of cell cultures.

(ii) Methods used for maintenance of cell cultures including medium, temperature and CO₂ concentration.

(iii) Test chemical vehicle, concentration and rationale for the selection of the concentrations used in the assay, duration of treatment.

(iv) Details of both the protocol used to prepare the metabolic activation system and of its use in the assay.

(v) Identity of spindle inhibitor, its concentration and duration of treatment.

(vi) Date of cell harvest.

(vii) Positive and negative controls.

(viii) Methods used for preparation of slides for microscopic examination.

(ix) Number of metaphases analysed.

(x) Mitotic index where applicable.

(xi) Criteria for scoring aberrations.

(xii) Type and number of aberrations, given separately for each treated and control culture, total number of aberrations per group; frequency distribution of number of chromosomes in established cell lines and strains.

(xiii) Dose-response relationship, if applicable.

(g) *References.* For additional background information on this test guideline the following references should be consulted.

(1) Ames, B.N., McCann, J., Yamasaki, E. "Methods for detecting carcinogens and mutagens with the *Salmonella*/mammalian-microsome mutagenicity test," *Mutation Research*, 31:347-364 (1975).

(2) Evans, H.J. "Cytological methods for detecting chemical mutagens," *Chemical mutagens, principles and methods for their detection*, Vol. 4, Ed. A. Hollaender (New York, London: Plenum Press, 1976) pp. 1-29.

(3) Howard, P.N., Bloom, A.D., Krooth, R.S. "Chromosomal aberrations induced by N-methyl-N'-nitro-N-nitrosoguanidine in mammalian cells," *In Vitro* 7:359-365 (1972).

(4) Ishidate, M. Jr., Odashima, S. "Chromosome tests with 134 compounds on Chinese hamster cells in vitro: A screening for chemical carcinogens," *Mutation Research*, 48:337-354 (1975).

(5) Preston, R.J., Au, W., Bender, M.A., Brewen, J.G., Carrano, A.V., Heddle, J.A., McFee, A.F., Wolff, S., Wassom, J.S., "Mammalian in vivo and in vitro cytogenetic assays: A report of the Gene-tox Program," *Mutation Research*, 87:143-188 (1981).

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§ 798.5385 In vivo mammalian bone marrow cytogenetics tests: Chromosomal analysis.

(a) *Purpose.* The *in vivo* bone marrow cytogenetic test is a mutagenicity test for the detection of structural chromosomal aberrations. Chromosomal aberrations are generally evaluated in first post-treatment mitoses. With the majority of chemical mutagens, induced aberrations are of the chromatid type but chromosome type aberrations also occur.

(b) *Definitions.* (1) Chromosome-type aberrations are changes which result from damage expressed in both sister chromatids at the same time.

(2) Chromatid-type aberrations are damage expressed as breakage of single chromatids or breakage and/or reunion between chromatids.

(c) *Reference substances.* Not applicable.

(d) *Test method*—(1) *Principle.* Animals are exposed to test chemicals by appropriate routes and are sacrificed at sequential intervals. Chromosome preparations are made from bone marrow cells. The stained preparations are examined and metaphase cells are scored for chromosomal aberrations.

(2) *Description.* The method employs bone marrow of laboratory rodents which have been exposed to test chemicals. Prior to sacrifice, animals are further treated with a spindle inhibitor,