Administrative Notice
March 1, 2012

To the sanitation departments and bureaus of all prefectures, cities with public health centers, and special districts,

Inspection and Safety Division,
Department of Food Safety,
Pharmaceutical and Food Safety Bureau,
Ministry of Health, Labor and Welfare

Concerning the Partial Revision of the Screening Method for Radioactive Cesium in Food Products

Screening for radioactive cesium in food products is being implemented with reference to the administrative notice “Concerning the Screening Method for Radioactive Cesium in Food Products” (October 4, 2011) (final revision: November 10, 2011).

Currently, as a new standard is to be established with regard to radioactive materials in food products in Article 11, Paragraph 1 of the Food Sanitation Act (Act No. 233 of 1947) with effect from April 1, 2012, we are writing to inform you of the changes as detailed in the attachment to this notice.

Although the revised Screening Method for Radioactive Cesium in Food Products is designed to accommodate the standards applied from April 1, 2012, if the Screening Method for Radioactive Cesium in Food Products is performed on food products that are subject to transitional measures after April 1, 2012, it will be possible to use the earlier unrevised version of the Screening Method for Radioactive Cesium in Food Products during the period of transitional measures.

The main changes accompanying this revision are as follows.

1. Food products subject to the Screening Method for Radioactive Cesium in Food Products are referred to as “general food products”.
2. Regarding the technical performance requirements specified in the Screening Method for Radioactive Cesium in Food Products, the screening level shall be at least one half (1/2) of the standard value (50 Bq/kg) and the lower limit of measurement shall be 25 Bq/kg (one quarter (1/4) of the standard value or less).

Administrative Notice
March 1, 2012

To all quarantine stations,

Inspection and Safety Division,
Department of Food Safety,
Pharmaceutical and Food Safety Bureau,
Ministry of Health, Labor and Welfare

Concerning the Partial Revision of the Screening Method for Radioactive Cesium in Food Products

Currently, we are notifying the sanitation departments (bureaus) of all prefectures, etc., with regard to the above subject.

(Attachment)

Screening Method for Radioactive Cesium in Food Products

1. Screening Method for Radioactive Cesium

Following the accident at Tokyo Electric Power Company's Fukushima Daiichi Nuclear Power Station, a wide range of food products have been contaminated with radioactive materials. To address this issue, test methods are to be monitored in accordance with the Manual for Measuring Radioactivity of Foods in Case of Emergency (hereinafter referred to as "the Emergency Manual") using the index values published by the Nuclear Safety Commission as the provisional regulation values.

In the Emergency Manual, the method of radionuclide analysis by means of gamma-ray spectrometry using a germanium semiconductor is specified as the method for measuring radioactive cesium. However, the means of efficiently inspecting a large number of samples are limited since the number of units of screening equipment that can be used in this method is limited and this method requires a relatively large volume of samples for measurement. Given this situation, a screening method has been established that can reliably identify samples with radioactive cesium concentrations lower than the provisional regulation value.

This time, Ministry of Health, Labor and Welfare's Pharmaceutical and Food Safety Bureau received a risk assessment report of the impact of radioactive materials in food on human health from the Food Safety Commission and a report from the Ministry's Pharmaceutical Affairs and Food Sanitation Council, which became effective from April 1, 2012 as a standard of the Food Sanitation Act (Act No. 233 of 1947). In response, the screening method was reviewed so that it could be adapted to the standard value of 100 Bq/kg for general food products.

Moreover, although the types of analytical equipment that can be used in the screening method are not precisely specified, they must meet the following performance requirements. Also, for specimens for which screening results do not fall below the screening level and where the radioactive cesium level cannot be reliably determined to be lower than the standard value, the test results shall be confirmed by means of a test method such as gamma ray spectrometry using a germanium semiconductor.

As an example of the screening analysis method, a method using a NaI (Tl) scintillation spectrometer is illustrated in Section 2 "Example Screening Method for Radioactive Cesium in Food Products." Other methods may also be used as long as they demonstrate the performance indicated in the analytical method.

For your reference, information on the screening method for radioactive cesium in food products and the concept of the measurement lower limit are attached, so please also check these

materials when conducting the screening method.

1. Analysis target	Radioactive cesium (Cs-134 and Cs-137)
2. Target food products	General food products
3. Analysis method	A method exhibiting the performance characteristics detailed below
Background value:	A value that can guarantee the following measurement lower limit. The background value shall be the value measured for the equivalent amount of water in the same container as the sample. However, if the shielding is sufficient, a measured value in a “blank” state (a state in which nothing is placed in the container) may be used as the background value.
Measurement lower limit:	25 Bq/kg (1/4 of the standard value) or less. Confirm that the following equation holds at 25 Bq/kg.

$$n_{s25} - n_b > 3\sqrt{\frac{N_{s25}}{t_s^2} + \frac{N_b}{t_b^2}}$$

Where: N_{s25} = A count of 25 Bq/kg

N_b = Background count

n_{s25} = 25 Bq/kg count rate (cps)

n_b = Background count rate (cps)

t_s, t_b = Sample and background counting period (s)

Trueness (calibration):	The counting efficiency must be calibrated using an appropriate standard source. Calibration should be performed at least once a year.
Screening level:	Must be at least 1/2 of the standard value. The upper bound of the 99% confidence interval of the measured value at the screening level must be less than or equal to the measured value obtained at the standard value level.

4. Test result reliability management

1) Measure the background on every test day and confirm that the measurement lower limit is not high.
2) Measure a blank container on every test day to ensure that the analytical system is free from radioactive surface contamination.
3) Measure a standard source or a sample of known concentration on every test day and confirm that the measurement trueness is unchanged.
4) Perform an energy calibration on every test day.
5) Since fluctuations in the air dose at the measurement location affect the background and changes in the temperature and applied voltage affect the results of energy calibration, take care to maintain the measurement environment in which calibration has been performed. If the above conditions change due to movement of the measurement location, etc., perform energy calibration and measure the standard source to confirm that the trueness is unchanged.
6) When packing the sample into the measurement container, take care not to create a gap especially near the detector.
7) Take care to avoid radioactive contamination of the surfaces of the analytical system from samples and also between samples. In particular, in order to prevent contamination of the detection unit, take measures such as covering the detector with a polyethylene bag and preventing the sample from becoming attached to the outside of the measurement container.
8) Take measures to prevent the mixing up of samples.

5. Recording of test results

The performance requirements of this screening method are set so that food products having a radioactive cesium concentration lower than the screening level can be determined as being below the standard value, and these requirements are not intended to obtain accurate measured values. Therefore, the test results obtained by the screening method should include the following information based on the above contents.

① Type of equipment used for measurement (e.g. NaI (Tl) scintillation spectrometer)

② Concerning the test results

- If the measured value is lower than the measurement lower limit, set the value to “less than the measurement lower limit (<25)” (when 25 Bq/kg is the measurement lower limit).
- If the measured value is higher than the measurement lower limit but lower than the screening level, record the measured value as a reference value.
- If the measured value is higher than the screening level, determine the test result by a test method such as gamma-ray spectrometry using a germanium semiconductor.

2. Example Screening Method for Radioactive Cesium in Food Products

In this section, an example is shown of a screening method for radioactive cesium using a NaI (Tl) scintillation spectrometer, which is currently in widespread use and considered usable as a screening method. How to determine the method's performance and points to note in analysis are also described. Other screening methods can also be used provided that the performance described in Section 1. "Screening Method for Radioactive Cesium" are satisfied.

1. The NaI (Tl) scintillation spectrometer

A NaI (Tl) scintillation spectrometer is a gamma-ray pulse height analyzer employing a sodium iodide (NaI) detector. Nuclide analysis is possible by measuring the fluorescence generated by irradiating the NaI crystal with gamma rays, but the energy resolution is lower than that of a germanium semiconductor detector. However, the equipment's counting efficiency is high, there is no need to cool the detector with liquid nitrogen, and maintenance is easy. For the purpose of measuring radioactive cesium, analysis can be performed by selectively counting the signals at the corresponding energy levels.

Commercially available NaI (Tl) scintillation spectrometers differ with respect to their NaI crystal size, measurable sample amount, measuring container, equipment weight, and degree of shielding. In addition, operability differs depending on the equipment, including with respect to measurement automation and portability. Accordingly, a suitable model should be selected after taking into consideration the amount of available samples, analysis time, operability, etc.

The conditions for using a NaI (Tl) scintillation spectrometer as the screening method for radioactive cesium in food products are described below.

1) Measurement energy range: The energy calibration of the equipment is periodically performed every test day using a sealed radiation source. Since NaI (Tl) scintillation spectrometers are generally sensitive to changes in ambient temperature and applied voltage, it is desirable to perform energy calibration each time a series of measurements is performed. The energy range corresponding to radioactive cesium gamma rays needs to be set appropriately in order to minimize effects of the other nuclides. Since gamma rays are emitted with different peak photon energy levels such as 662 keV from Cs-137 and 605 and 796 keV from Cs-134, a range in which these various gamma rays can be measured correctly must be appropriately set in consideration of the equipment's counting efficiency and the background count. If the energy range is widened, while counts derived

from radioactive cesium will increase, counts from the background and effects from the other nuclides will also increase. If the status of the other nuclides in the environment or in the sample changes, it is necessary to reconfirm the energy range setting.

2) Calibration: As time passes since the nuclear accident, radioactive iodine (I-131) has decreased to a negligible level, and radioactive cesium (Cs-134 and Cs-137) have become the dominant nuclides. If all of the detected radiation is considered as being derived from radioactive cesium, this will result in a positive bias in the analysis results, but the bias is small for the reasons mentioned above and a positive bias is acceptable for this screening method. Conversely, when compensating for effects of the other nuclides, care must be taken because accuracy may be reduced and a negative bias introduced. When all the detected radiation is considered to be from radioactive cesium, since in general the counting efficiency for Cs-134 is higher than for Cs-137, calculating the counting efficiency for Cs-137 alone produces a positive bias. Since this is suitable for the purposes of the screening method, in practice it is effective to calibrate with Cs-137 alone. However, calibration is also possible using Cs-134 and Cs-137. In either case, it is important not to underestimate the amount of radioactive cesium by paying attention to the ratio of Cs-134 and Cs-137 at the measurement period, etc. Calibration of the equipment can be performed with reference to the information from the equipment maker. However, since the counting efficiency varies under different conditions, the conditions for calculating the counting efficiency such as the choice of calibration nuclides and the shape of the radiation source must also be obtained.

3) The measurement lower limit depends on the background count as well as on the equipment's counting efficiency and the measurement time. It is essential to prepare a measurement environment that provides background conditions that can satisfy the measurement lower limit. For this purpose, the measurement sample and the detector are shielded by lead, etc. in order that influences from the environment are reduced. Unless the background conditions satisfy the measurement lower limit, this method cannot be used as a screening method.

4) Since changes in the background count and temperature affect measurement, care should be taken to maintain the measurement environment in which calibration was performed. If the conditions change, perform energy calibration and measure a standard source or a sample with a known concentration to confirm the measurement accuracy.

5) Since the measurement results are affected by the geometry (spatial positional

relationship) between the sample and the detector, in order to determine the equipment's counting efficiency, evaluate the background, and measure samples, it is necessary to use the same measurement container as much as possible and to fix the relative positions of the detector and measurement container. Moreover, it is important to match the conditions for calculating the equipment's counting efficiency and the measurement conditions of the actual sample including the measurement container as much as possible, and to pay particular attention to the conditions (distance, material) close to the detector. If these conditions differ even slightly, correction may be required.

2. How to Confirm the Performance as a Screening Method

Confirming the measurement lower limit

The case of a general food product with a standard value of 100 Bq/kg is shown as an example. In this case, the measurement is performed under the condition that the net count of 25 Bq/kg (measurement lower limit value) is greater than three times the standard deviation σ of the accompanying error.

The standard deviation σ of the error of the net count rate is obtained by the following equation.

$$\sigma = \sqrt{\frac{N_s}{t_s^2} + \frac{N_b}{t_b^2}} = \sqrt{\frac{n_s}{t_s} + \frac{n_b}{t_b}} \qquad \text{Equation 1}$$

However,

Where: t_s, t_b = Sample and background counting period s

N_s = Sample count

N_b = Background count

n_s = Sample count rate cps

n_b = Background count rate cps

since the net count rate at 25 Bq/kg is larger than 3 σ ,

$$n_{s25} - n_b > 3\sqrt{\frac{N_{s25}}{t_s^2} + \frac{N_b}{t_b^2}} \qquad \text{Equation 2}$$

Where: N_{s25} = A count of 25 Bq/kg

N_b = Background count

n_{s25} = 25 Bq/kg count rate cps

n_b = Background count rate cps

t_s, t_b = Sample and background counting period s

the measurement conditions are set to satisfy the above condition. The left side is the net count rate, which is determined by the sample amount and the performance of the equipment. Therefore, in order to establish the formula, the background count on the right side needs to be reduced.

Confirming the screening level

Confirm that the upper bound of the 99% confidence interval of the distribution of screening level measured values (1/2 or more of the standard value) is less than the measured value obtained using the standard value. The following is a conceivable method of obtaining the upper bound of the 99% confidence interval of the distribution of measured values, but other methods that are statistically correct may also be used.

1) Repeated measurement method

Measurements are made repeatedly at the screening level, and the upper bound of the 99% confidence interval is determined from the average and standard deviation of the measured values by means of the following formula. These measurements are performed under the same conditions as the actual sample measurements, including as much as possible any factors that affect measurement variation. The number of repetitions shall be five or more. If the background is kept low and the measurement lower limit is secured, it is possible for the equipment manufacturer to guarantee the screening level in terms of the equipment's performance.

The upper bound of the 99% confidence interval of the measured value distribution =

$m + t_{k-1,0.01} \times s$ Equation 3

Where: m = Average of measured values

s = Standard deviation of measured values

k = Number of measurements

$t_{k-1,0.01}$ = t value with k-1 degrees of freedom and one-sided critical value of 1%

2) Regression line prediction interval method

Multiple samples are measured with the radioactive cesium concentration in the range of 0-100

Bq/kg and the upper bound of the 99% prediction interval of the regression line is determined.

Upper bound of the 99% prediction interval of the regression line =

$$m+\sqrt{V_e\left\{1+\frac{1}{n}+\frac{(x-\bar{x})^2}{S_{x\ x}}\right\}}\times t_{n-2,0.0\ 1} \qquad \text{Equation 4}$$

Where: m = Measured value at concentration x expected from regression line

Ve = Error variance of regression line

n = Number of data used for regression

x = Radioactive cesium concentration

$\bar{x}$ = Average radioactive cesium concentration used for regression

S_{xx} = Sum of squares of radioactive cesium concentration used for regression

Converting count rate to radioactivity concentration

The radioactivity concentration is calculated from the net count rate (the difference between the count rates of the sample to be measured and the background), the equipment conversion factor, and the sample weight.

$$\frac{(n_s-n_b)\times K}{W}=C \qquad \text{Equation 5}$$

Where: n_b = Background count rate (cps)

n_s = Sample count rate (cps)

K = Equipment conversion factor (Bq/cps)

W = Sample weight (kg)

C = Radioactive cesium concentration (Bq/kg)

In this screening method, if the sample weight is constant, the result can be determined from the count rate, so that conversion from the count rate to the radioactivity concentration is not mandatory.

3. Examples of measurement methods

3.1 Setting the energy range

Since Cs-137 emits gamma rays at a peak energy level of 662 keV while Cs-134 emits at peaks

of 605 keV and 796 keV, the energy range is set using Cs-134. As described in above 2.1-1), if the energy range is widened, while counts derived from radioactive cesium increase, counts from the background and effects from the other nuclides also increase. The ratio of the standard deviation of the error associated with the net count to the net count is extremely small when the energy is in the range of 540 to 830 keV, so it is desirable to set the energy range close to this value.

3.2 Determining the equipment conversion factor

Using a Cs-137 standard source, the equipment conversion factor is determined in the set energy range. Since the equipment conversion factor depends on the measurement container and the geometry, if these things change, it is necessary to determine the equipment conversion factor again.

3.3 Sample measurement

The count rate of a sample is obtained in the set energy range, and the net count rate is obtained by subtracting the background count rate. The radioactive cesium concentration in the sample is determined by using the conversion formula (Equation 5) from the net count rate to the radioactive cesium concentration as shown in 2.2. "How to Confirm the Performance as a Screening Method," above. Since the equipment conversion factor is determined using a Cs-137 standard source, the count rate from Cs-134 is also obtained as a count rate deriving from Cs-137. For this reason, the obtained radioactive cesium concentration is slightly higher than the actual total radioactivity, but since Cs-134 has a shorter half-life than Cs-137, the ratio of Cs-134 to Cs-137 gradually decreases, and the measured values approach the actual radioactivity level.

Notes

Individual quantification of Cs-134 and Cs-137

If the main nuclides contained in the sample are limited to Cs-134 and Cs-137, it is possible to individually quantify the Cs-134 and Cs-137 by separating and analyzing the gamma rays emitted from each nuclide and calibrating against the standard source of each nuclide. However, since the standard value is set as the sum of the two nuclides, Cs-134 will decrease in the future, and the screening method allows for a positive bias, there is no need for individual quantification.

When performing individual quantification of Cs-134 and Cs-137, since the trueness and accuracy of the results depend on the analysis algorithm used, it is necessary to confirm that there

is no negative bias exceeding the estimated fluctuation range in the analysis results by using a mixed standard source or a sample with a known concentration. Also, the peak area depends on the fitting analysis and the peak-to-baseline ratio of overlapping double peaks, which may lower the screening level. It is necessary to confirm the method of calculating the peak area with the software developer.

Correction of effects of other nuclides

Food samples may contain K-40, which increases the count in the measurement range due to the Compton effect and creates a positive bias. Since the screening method allows for a positive bias, there is no need to correct for this. When performing correction, it is necessary to check the measurement lower limit and to confirm that the correction is not excessive and does not cause a negative bias, so please confirm this with the software developer.

4. Applicable food products

The amount that can fill the measurement container differs depending on the type of food, and the lower limit of measurement also changes accordingly. In general, n_{s25} is obtained when the specific gravity of water, etc., is close to 1. Assuming that the ratio between the filling amount of the food to be measured in the container and the filling amount of water (the filling rate) is ρ, the net count rate $n_{s25}-n_b$ changes to $(n_{s25}-n_b)\times\rho$ and

$$(n_{s25}-n_b)\times\rho > 3\sqrt{\frac{(n_{s25}-n_b)\times\rho+n_b}{t_s}+\frac{n_b}{t_b}} \qquad \text{Equation 6}$$

needs to be established. For this reason, the range of ρ in which Equation 6 is satisfied is obtained in advance, and the screening method can be applied when the filling rate is within the range where Equation 6 is satisfied. Similarly, confirmation of the screening level also takes the filling rate into account.

The general range of ρ is approximately 1 for fish, meat, and eggs, but becomes slightly smaller for foods that contain more fat. For vegetables including fruits, tomatoes and root vegetables the range is close to 1, but for chestnuts it is around 0.8. Care must be taken as the amount of leafy vegetables varies greatly depending on the filling method. The range for cereals such as rice and wheat is 0.85 or more. For foods such as dry products with a ρ value of 0.5 or less should be checked for each test to determine whether this screening method can be applied.

Reference:

Japan Science and Technology Agency, 1974. *Radioactivity Measurement Series No.6: Analysis Method using NaI (Tl) Scintillation Spectrometer*

For information on simplified analysis of radioactivity in food products based on the Manual for Measuring Radioactivity of Foods in Case of Emergency (information provision, follow-up report), please visit the following link: http://www.jrias.or.jp/index.cfm/6,15496,110,html

(Reference)

Concept of the Screening Method for Radioactive Cesium in Food Products

The screening method for radioactive cesium in food products indicated in the present administrative notice is the first radioactive cesium test method to be clearly indicated for food-related tests, and moreover, many inspectors are considered to be unfamiliar with radiological test methods. Accordingly, this reference material has been prepared in order to explain the concept of this screening method.

1. Screening method

The purpose of these tests is to prevent the distribution of food products regulated under the Food Sanitation Act. Therefore, the performance of the tests is evaluated based on the probability of a sample (food product) complying with the standard being passed? a test and the probability of a sample not complying with the standard being rejected. If the probability of both outcomes is high, the performance of the test can be said to be high. Figure 1 shows the performance of an ideal test and an actual test in the form of operating characteristic (OC) curves. The horizontal axis shows the concentration of the regulated object (in this case, radioactive cesium) in the sample, and the vertical axis shows the pass rate of the samples. In the ideal test shown by the dotted line, food products with a radioactive cesium concentration slightly exceeding the standard value of 100 Bq/kg fail the test, while those with a concentration slightly below 100 Bq/kg pass. In the test, passing or failing is determined based on the measured value of the radioactive cesium concentration. Since the measured values are accompanied by uncertainties and measurement results can vary even for the same sample, the performance of the actual test yields the curve represented in the figure by a solid line. The slope of the curve close to the standard value varies depending on the measurement accuracy: the higher the accuracy, the steeper the slope.

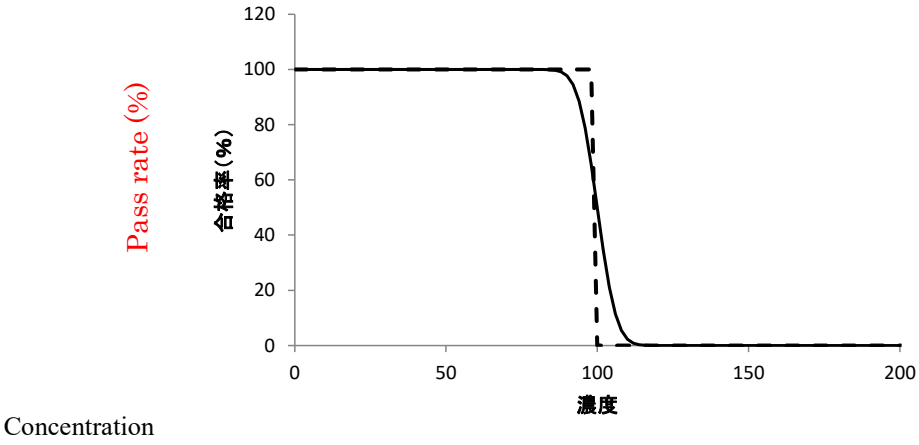

Figure 1. Test OC curves

Figure 2 shows the performance of an test based on measurements with low accuracy or a large degree of uncertainty in the measurement results. In this test, 25% of the samples pass even when their radioactive cesium concentration is 110 Bq/kg, and 10% fail even when their radioactive cesium concentration is 80 Bq/kg, so the performance of the test is low. Conversely, if the performance (of an test) is evaluated from the standpoint in which food products complying with the standard should pass, since food product samples with a concentration of 50 Bq/kg should always yield a result of <100 Bq/kg, the test's performance is high enough to pass 100% of samples with a concentration below 50 Bq/kg. Consequently, this test has a performance in which samples that yield a result of 50 Bq/kg or less will pass.

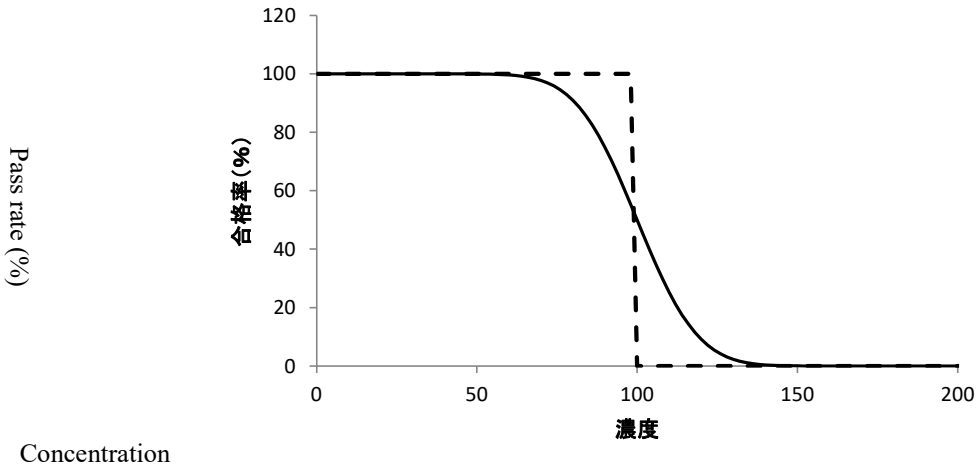

Figure 2. Test performance based on inaccurate measurements

The performance required of a screening test is that food products with a radioactive cesium

concentration below a certain concentration can be judged to be below the standard value with a probability of close to 100%. Food products that pass according to this test method can be considered compliant with the standard value. Based on this concept, the administrative notice refers to “a screening method has been established that can reliably identify samples with radioactive cesium concentrations lower than the standard value.” On the other hand, since the performance of this screening method in making decisions on compliance or non-compliance for food samples containing cesium in excess of the screening level is poor, it is necessary to determine the test results for these samples by a confirmatory method.

When performing this screening method, if the screening level that can be reliably determined to be lower than the standard value is high, the proportion of the samples screened increases so that the efficiency of the test will become high. Figure 3 shows the performance of an test based on very low-accuracy measurements. Using such a method, the proportion of the samples screened is low and the efficiency of the test does not improve.

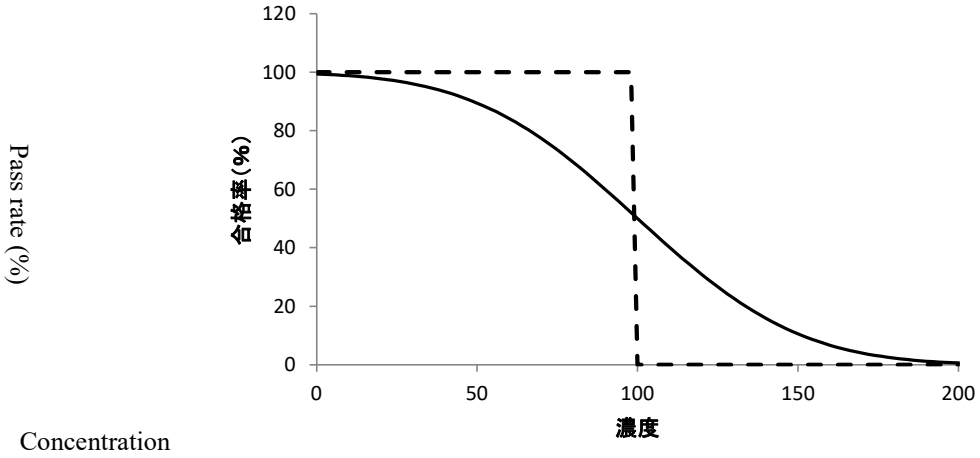

Figure 3. Test performance based on extremely low-accuracy measurements

Even if the measurements are precise but the accuracy is inappropriate, it may be possible to use the method for screening tests. Figure 4 represents an test based on measurements that have a positive bias. Since the results are always higher than the actual concentration, the pass rate at the standard value level is low and so the method cannot be used for ordinary test. However, when the concentration in a sample is 60 Bq/kg, a result of <100 Bq/kg is always obtained, so this test can be said to have a performance in which 100% of samples with a concentration of 60 Bq/kg or less will pass. Accordingly, a screening test based on these measurements is possible.

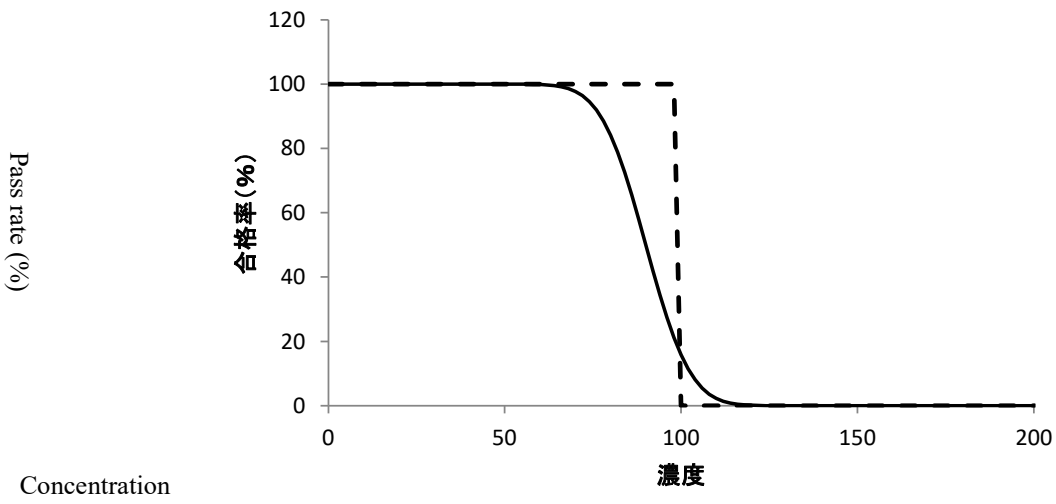

Figure 4. Test performance based on measurements with a positive bias

The discussion so far has defined the performance of screening tests at the screening level. As long as the screening level is appropriate, the method will be effective as a screening method, but this does not mean that it will be a simple test method. A simple test method is defined by the characteristics of the measurement method, such as being easy to operate and not requiring expensive equipment, but since its measurement accuracy and its screening level may be unknown, it cannot always be adopted as a screening method. In order to adopt a simple method as a screening method, it is necessary to confirm its screening level.

2. Performance requirements

As described above, it is a necessary condition for a screening method to have an appropriate screening level. The screening level is determined such that the upper limit of 99% of the distribution of measured values at that level (the count rate or the radioactive cesium concentration of the sample if using an NaI (Tl) scintillation spectrometer exemplified in this document) is lower than the measured value of the standard level. If the sample weight decreases due to the filling rate of the measuring container, it is necessary to consider the influence of the filling rate on the measurement lower limit and the concentration.

When the instrument counting efficiency changes, the screening level changes accordingly, so it is important to perform calibration against an appropriate source.

At present in Japan, levels of environmental radiation are not constant, and there are places

where the levels are extremely high. Environmental radiation is measured by measuring equipment as a positive signal and is highly likely to fluctuate rather than to remain constant. For this reason, environmental radiation is a major factor in reducing measurement accuracy. Accordingly, the background value and the measurement lower limit obtained from this value are added to the performance of the test as a screening method.

The screening level is related to the accuracy of the assay. Factors including variations in the count value and the geometry can cause radiation measurement results to vary and reduce their accuracy. Radiation measurement counts follow a Poisson distribution. If the count is *N*, the standard deviation is $\sqrt{N}$. Since the net count rate is obtained by subtracting the background count rate from the count rate, the standard deviation derived from the background count also has an effect on the precision of the assay. In addition, since the geometrical changes between the sample and the detector affect the instrument's counting efficiency, the accuracy of measurements in which the geometry is not constant is further reduced.

If the background is sufficiently small, the degree of fluctuation in the measurement results will be determined by the measuring equipment, the measuring container, and the degree of the geometrical changes between the detector and the measuring container. Accordingly, under the sufficient low background conditions at the time of measurement, it is possible for the equipment manufacturer to indicate the screening level as the performance of the equipment. If the measurement is performed properly using the measurement time and the measuring container recommended by the equipment manufacturer, the screening level provided by the equipment manufacture can be guaranteed. However, when using containers other than those recommended by the equipment manufacturer, or when performing measurements in which the geometry between the measurement container and the detector change for each measurement, it is necessary to confirm the screening level of the measurement system.

The background and measurement lower limit are affected not only by the performance of the equipment, but also by the measurement environment.

$$n_{s25} - n_b > 3\sqrt{\frac{n_{s25}}{t_s} + \frac{n_b}{t_b}} = 3\sqrt{\frac{N_{s25}}{t_s^2} + \frac{N_b}{t_b^2}}$$

Equation 7

Since the background count rate n_b works to make the left side small and the right side large, this formula cannot be satisfied if n_b is large. Therefore, it is vitally important to reduce n_b using

sufficient shielding.

The Concept of the Measurement Lower Limit

In the measurement of radioactive cesium concentrations by NaI (Tl), the number of gamma rays incident on the detector within the measurement time (the count value) N is the primary measurement value. N is assumed to follow a Poisson distribution, with a variance N and a standard deviation $\sqrt{N}$. From this property, the standard deviation of the counts associated with the measured values of radioactive cesium can be estimated from a single measurement result without having to rely on repeated measurements. In this respect NaI (Tl) measurement differs significantly from general chemical substance measurement.

In the measurement of the radioactive material concentration, the count rate $n_s = N_s/t_s$ is obtained from the count value N_s, and the radioactive cesium concentration C is calculated from the difference from the background count rate n_b and the net count rate.

With $n_s = \frac{N_s}{t_s}$, the standard deviation with n_s becomes $\sqrt{N_s/t_s^2}$. Even if the same count rate is obtained by the measurement, the standard deviation differs depending on the count value N and the measurement time t_s. The ratio of the standard deviation of the count rate to the count rate is $\frac{\sqrt{N_s/t_s^2}}{N_s/t_s} = \frac{1}{\sqrt{N_s}}$ Equation 8

and the relative standard deviation of the count rate decreases as the count value increases. The standard deviation σ associated with the net count rate $n_s–n_b$ is the square root $\sqrt{N_s/t_s^2 + N_b/t_b^2}$ of the sum of squares of the standard deviation $\sqrt{N_s/t_s^2}$ associated with n_s and the standard deviation $\sqrt{N_b/t_b^2}$ associated with the background count rate n_b.

In the evaluation of the measurement lower limit, the net count rate is required to be three times σ at a concentration of 1/4 of the standard value. In chemical analysis, the standard deviation of the blank measurement value is considered to be the same when measuring concentrations close to the detection limit, and the detection limit is often defined as three times

the blank standard deviation value. In this case, the measurement result is three times the standard deviation. Although the net count rate at the measurement lower limit is three times higher or more than the standard deviation, the difference is that the standard deviation σ is not obtained from the blank measurement value but is instead obtained from the sample and background counts.

At the screening level as well, the standard deviation σ can be estimated by substituting a value of 50 instead of 25 into the right-hand side of Equation 7. The σ obtained in this way is used as s in Equation 3 to calculate the 99% upper limit of the measured values at the screening level. For example, for a Gaussian distribution, 2.33 is used instead of t. However, since this method takes into account only the uncertainty of the counting statistics, a condition for applying this method is that in the case of repeated measurements the standard deviation s in Equation 3 is not abnormally large compared to the standard deviation σ estimated from a single measurement.