Causes of Exposure Rate Increase in the Air and Water Monitoring

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INTRODUCTION

The monitoring of gamma exposure levels in the air and water has been carried out to demonstrate the safe operation of the facilities or the radiation sources. The radiation levels have been measured by NaI(Tl), GM or pressurized ionization chambers for the air monitoring and NaI(Tl) for the water. Although NaI(Tl) detector can provide energy spectrum of gamma rays coming into the detector, total count rate or exposure rates obtained by weighting the energy spectrum with GE function are usually used for the monitoring of radiation level since it is simpler, easy to handle and requires less memory than the spectrometric data. GM counter or ionization chamber can provide only gross counts or exposure rates. The ambient radiation level is not constant. It fluctuates time to time due to many causes. However, the causes of the fluctuation of the radiation levels could not be easily identified by the gross count measurements since the information is far less than the spectrometric data. It is important to understand the phenomenon of monitoring level fluctuation due to natural causes since the original purpose of the monitoring is to find artificial contributions to the radiation levels.

Some of the known causes for the monitor in the air are statistical fluctuation, plateout of radon daughters due to rain, snow cover on the ground and water content in the soil. The fluctuation of water monitor is also caused by rain with radon daughters and soil suspension in the water. For the monitoring of artificial radiation it is necessary to clarify the fluctuation due to natural causes. Some parameters, such as rain, wind and others are useful information for the identification of the causes. In case other information is not available it turns to be far more difficult to identify the cause of the radiation level fluctuation. In the present paper the typical patterns of radiation level increase are characterized based on the actual monitoring data.

METHOD

Monitoring data in three different regions were investigated in the present paper to find the causes and to estimate the range of their fluctuation. Each region has more than three monitoring sites. Each monitoring site has records of continuous measurement of exposure rates obtained by NaI(Tl) detector as well as of rainfall and rain intensity. More than three years of those continuous data were analyzed by checking the coincidence of radiation level increases among several monitoring sites as well as rainfall and rain intensity data with other information such as performance of industrial radiography which uses Ir gamma source near the monitoring site or observation of soil suspension in the water. Experimental simulation of source contact to the detector was also conducted using monazite stones or soil for the water monitor in order to observe the detector response to rainwater with radon daughters or the soil suspension in the water. Original intention of Adjoint Monte Carlo simulation has not been carried out and been postponed for a future investigation. Significant radiation level increases were selected from the chart data. When one of the detector's levels is significantly high all records of other detectors and rainfall data were collected in addition to other information. Then the patterns of the increase of radiation levels were classified into several typical types.

OBSERVATION AND DISCUSSION

Typical patterns of radiation level increase were chosen for air monitors and water monitors.

Pattern 1: Increase with rain

Radiation levels in the air as well as water sometimes increase with rain. This is due to rainout and washout of radon daughters. The increased level in the air monitor is relatively high especially in the case of thunderstorm. The level will go up to several times higher than the normal level. In the case of water monitor the increase goes up to a few tens times of the normal level. In addition, water monitor sometimes shows a sharp increase due to rain in contrast to the air monitor.

In the air monitoring the increase of radiation levels is observed at all monitoring sites with a similar pattern as far as rain is observed at all sites. The increase of radiation level should coincide with the beginning of the rain. However, small increase might be found with a weak rain, which is undetectable by rainfall detector. The radiation level in the air monitor does not show sharp increase or decrease by the rain. It usually increases and decreases gradually. Sometimes, the higher level continues for more than a few days with continuous rain.

Water monitor will not always increase with rain. The increase of water monitor usually starts 30 to 60 minutes after the beginning of the rain. However, when it rains not at the monitoring site but at the upper stream of the river the relationship between the increase of the radiation level and the initiation of the rain does not follow the abovementioned rule. The water monitor might show a sharp increase of the level due to rain. It does not always synchronize the increase of air monitor with water monitor. Only one water monitor could show the increase in contrast to the air monitor. The higher level of radiation will decrease with the half-life of 30 to 40 minutes. When the sharp peak is observed in the water monitor, the half-life of the decrease should be obtained from the area after the sharp peak.

Pattern 2: Industrial radiography

The usage of gamma sources near the monitoring site by industrial radiography increases the radiation level only for the air monitor regardless of rainfall. The increase is sharp and the radiation level fluctuation shows a pulse or rectangular shape. No increase could be found by the industrial radiography for the water monitor.

Pattern 3: Soil suspension in water

Soil suspension in the water near the water monitor could increase its radiation level since the radioactivity in the soil is higher than the potassium content in the seawater. However, the increase level could not be large because suspended soil volume is small compared to the normal soil density in the ground.

Pattern 4: Contact of water monitor with the sediment

Water monitor could be loosened from the original position and reach or be close to the bottom of water. Then the monitor will receive gamma rays from the bottom soil and show the increase of radiation level. Experimentally the detector was lowered to the bottom of the water to know the degree of the increase. The increase level was around a few times the normal level for the normal soil although the degree of the increase totally depends on the radioactivity in the bottom soil.

Pattern 5: Exposure of water monitor to air

The water monitor is designed to monitor the radioactivity in the water. It must be located in the water at least 80cm below the water surface. When the monitor is located less than 80cm below the water surface the detector will receive the radiation outside the water. Therefore, the monitor is carefully situated in the water where the upper layer of water should be deep enough to absorb the radiation coming from the air. However, in shallow seashore the depth of upper layer of the water could not be the main constraint. If the detector is placed deep enough in the water, then the detector becomes close to the bottom of the sea. When the monitor is placed in the seashore the ebb and flow of the sea must also be considered. When the monitor is placed in the river the variation of water level should be taken into account.

Especially when the big ebb tide or tsunami occurs the monitor may be exposed to air or the water depth turns to be small, then the radiation level increases since the exposure level in the air is larger than that in the water.

Pattern 6: Mechanical failure

Some mechanical failure causes sharp decrease or increase of radiation levels. The phenomenon is found several monitors at the same time if the monitors use the same electric circuit.

CRITERIA FOR DEFINING CAUSES

Following requirements should be fulfilled to identify the cause of the fluctuation of the radiation level. If some requirement could not be satisfied, then the fluctuation might be caused by other factor.

Requirement for Pattern 1: Increase with rain

For the identification that the cause is the rain following requirements should be satisfied.

For air monitor:

C1 The increase of the level should be coincided with the beginning of the rain recorded on the chart of rainfall and rain intensity.

C2 All monitoring sites should show the similar pattern at the same time as far as it rains at all monitoring sites.

C3 The exposure rate level should have a relatively smooth time trend.

C4 The recovering time of exposure rate to normal level should have a half-life of 30 to 40 minutes, which reflects the half-life of radon daughters.

For water monitor:

C1 In the air monitor the increase of the level should be coincided with the beginning of the rain recorded on the chart of rainfall and rain intensity. And the increase of water monitoring level should follow the air monitor with a time delay of 30 to 60 minutes. However, if the rain in the region of upper stream is observed the criteria above could be neglected.

C2 The recovering time of exposure rate to normal level should have a half-life of 30 to 40 minutes. When the water monitor has a sharp peak of increase the half-life should be calculated in the records after the peak.

C3 The water monitor which shows the increase should be located where river water can easily access to the detector.

Requirement for Pattern 2: Industrial radiography

C1 The increase is found only in the air monitor.
C2 The increase shape should be very sharp.
C3 The recovery shape also should be very sharp.
C4 After a certain time of increase the level should return to the same level just before the increase.
C5 The duration of the increase should be 5 to 15 minutes, that is the normal duration of irradiation for industrial radiography.
C6 The sharp increase should be found only at one monitoring site.
C7 The similar increase should not be found at the same time for the water monitor.
C8 It might be preferable to obtain the information of the time of usage of radioactive source from the radiography company.

Requirement for Pattern 3: Soil suspension in water

C1 The increase is found only in the water monitor.
C2 The degree of the increase could not be large. It could not reach to the level of three times larger than the normal level.
C3 No other water monitor shows similar pattern at the same time.
C4 The water monitor, which shows the increase, should be located where soil suspension could happen.
C5 When the soil suspension is caused by the river water, then the increase could return to normal level within shot time. On the contrary, the soil suspension caused by some construction near the water monitor, then the increase could remain for a certain period.

Requirement for Pattern 4: Contact of water monitor with the sediment

C1 The increase should be found only one water monitor.
C2 The increased level should be maintained and no decline of radiation level should be observed.
C3 The increasing rate of radiation level could be slow or rapid depending on the way of loosing the water detector.
C4 Check the position of the water monitor in the water.

Requirement for Pattern 5: Exposure of water monitor to air

C1 The increase should be found only water monitors.
C2 No synchronized increase should be found in the air monitor.
C3 The water monitor which is placed in the shallow seashore could be found the effect of ebb and flow of the sea. The depth of each water monitor should be measured.
C4 Check the coincidence of the happening of big ebb tide with the radiation level increase.
C5 Check the effect of Tsunami.

CONCLUSION

The largest perturbation cause is found to be rain or rainwater that sometimes contains large amount of radon progeny accumulated by rainout and washout. The radon progeny in rain are deposited on the surface of the ground or accumulated in the river water and result in a significant increase of the air or water monitor level. The exposure rate could be increased to the level which is several times higher than the normal one depending on the intensity and type of rain. The increase due to rain could reach to a few tens times higher value than the normal level in the water monitors. The contribution due to soil suspension in water to the water monitor could not be so high as to compare with the contribution from radon progeny in rainwater. The findings in the present evaluation help to identify the cause of fluctuation observed in monitoring data in the air and water. It could also be useful to avoid misjudgment that artificial radiation is the cause of noticeable increase of the monitoring level although it originates from one of the natural phenomena. Provision of typical patterns of radiation level increase is a skillful tool for the quick judgement of increases in the monitoring data. In addition the presentation of typical patterns will help to promote the understanding of radiation by the general public.