# Characteristics of gamma-ray dose-rate enhancement observed during winter thunderstorms

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The environmental radiation monitors are set up around a nuclear power plant in order to monitor gamma-ray dose-rate from the plant operation, and measured the gamma-ray dose-rate around the monitors continuously. We have carried out the environmental radiation monitoring by setting up 12 monitoring post/stations around the Fugen nuclear power station and the Monju construction office of JNC (Tsuruga City, Fukui Pref.). All the monitoring posts/station have two detector systems: a cylindrical NaI(Tl) scintillation detector and a pressurized spherical ionization chamber. These instruments, of course, also detect natural variations of radiation, and the transient dose-rate increasing observed occasionally only during winter thunderstorms.

As the result of our measurements, the following features are clarified from the measured data of the monitors with NaI(Tl) detectors, which are by far difficult to be affected by electromagnetic noises compared with the ionization chambers:

1. Almost all dose-rate increases during thunderstorms are from several to several 10 times of the background levels at each monitoring point.
2. The rise times of the dose-rate increase are about several ten seconds.
3. The affected areas of the enhanced radiation seemed to be quite local, because in most cases, only one or two of the monitoring posts/stations situated several hundred meters away from each other showed dose-rate increases.
4. The starting time of the dose-rate increase of two monitoring posts/stations at a position several 100 meters away is not always be simultaneously, and time lags of 10 – 20 seconds are sometimes observed.
5. It is not always coincided with the time of the cloud-to-ground lightning discharges recorded by the Lightning location system (LLS) and that of dose-rate increases observed, and the dose-rate increases might occur at the time not recorded by the LLS.
6. At the time of dose-rate increasing, the dose penetration rate, which indicates the effective energy of radiation, is also higher than that at usual time. This suggests that energetic radiation might be emitted at that time.

These features indicate that the observed phenomena can be attributed to the strong electric field inside thunderclouds, not to the individual lightning discharges. Furthermore, it seemed that the bremsstrahlung photons generated by the runaway process of high energy electrons accelerated by the strong electric field in the thundercloud.

We report on the feature of the dose-rate increasing during winter thunderstorms together with the measured results.