RADIOLOGICAL IMPACT OF A NATURAL GAS POWER PLANT

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Although natural gas (NG) is regarded as cleanest among all fossil fuels, it is not necessarily so clean in radioactivities. Some NG, especially those of U.S.A. and Canada, contain a large amount of radon. Two of radon daughters, ^{210}Pb and ^{210}Po, are very important in the pathway through seafoods as already reported in the last IRPA Congress for a coal-fired power plant, and they are important for an NG power plant also. Another possibility is chromosome aberration of the public near an NG power plant. Since RBE of α vs. β in chromosome aberration is very high, α-activities from a thermal power plant could have a considerable effect. Preliminary estimates have shown that the effect of an NG power plant using some American or Canadian gas could be high enough to cause observable chromosome aberration in the public near the power plant. Since the radioactive contamination due to an NG power plant has been completely overlooked, due care must be given to this possibility.

1. RADON AND ITS DAUGHTERS IN NATURAL GAS

Natural gas (NG) is usually believed as cleanest among all kinds of fossil fuels. For chemical pollutants this is true, but for radioactivities it is not necessarily true. Some of NG, especially those of U.S.A. and Canada, contain a large amount of radon. According to UNSCEAR1982 (1) in ordinary NG the radon concentration is of the order of 1-10 pCi/l, whereas in some American or Canadian NG it is as high as 100-1000 pCi/l.

Although ^{222}Rn itself is short-lived (3.8d), its daughter, ^{210}Pb, is long-lived (22y) and hence may remain in the gas to be emitted from an NG power plant. As already reported in the last IRPA Congress (2), ^{210}Pb and its daughter ^{210}Po (138d) are important in its relation to the pathway through seafoods. Although the dose due to them is probably smaller than the previous estimate (2) when newer data of ^{210}Pb of seafoods near Japan (3) are used (as discussed later), they are still important radionuclides.

Therefore, to assess the radiological impact of an NG power plant not only the concentration of ^{222}Rn but also those of ^{210}Pb and ^{210}Po must be known. They are measured for NG of the North Sea by Wilkins (4). The results are, on the average, about 1 pCi/l for ^{222}Rn, 0.4-0.6 fCi/l for ^{210}Pb, and the ratio of ^{210}Pb to ^{222}Rn is $4\text{-}6 \times 10^{-4}$, which is just about equal to the ratio of their half lives, namely $3.8d/22.3y = 4.7 \times 10^{-4}$.

This shows that, while in an NG well ^{222}Rn and ^{210}Pb are in equilibrium, ^{210}Pb is completely removed when the gas is extracted and only ^{222}Rn remains, which decays to ^{210}Pb. The ratio of $^{210}Po/^{210}Pb$ in this measurement is 0.1-0.5, but this is probably because the gas is extracted from the North Sea NG well and is transported to the mainland of the United Kingdom, which takes a short time, and hence ^{210}Po has not yet reached an equilibrium with ^{210}Pb. After a sufficient time ^{210}Po reaches equilibrium. Therefore, in the following calculation the ratio of $^{210}Po/^{210}Pb$ is taken to be 1.

2. RELEASE RATES FROM A POWER PLANT AND COMPARISON WITH A COAL-FIRED POWER PLANT

A 1000 MW NG plwer plant with a capacity factor of 80% consumes NG of about $1.8 \times 10^9 m^3/y$. Assuming ^{210}Pb and ^{210}Po concentrations of 0.4-0.6 fCi/l, the amount of ^{210}Pb and ^{210}Po in this volume of NG is 0.7-1.1 mCi/y. Usually the dust removal is not made for an NG power plant because it is believed to be clean, all of these ^{210}Pb and ^{210}Po are expected to be released, and hence their release rates are 1 mCi/y. Since the ^{210}Pb and ^{210}Po concentration of 0.4-0.6 fCi/l corresponds to about 1 pCi/l of ^{222}Rn, an easy conversion formula of the ^{222}Rn concentration in NG and the release rates of ^{210}Pb and ^{210}Po from a 1000 MW NG power plant with 80% capacity factor is

$$1 \text{ pCi/l of } {}^{222}Rn \longrightarrow 1 \text{ mCi/y of } {}^{210}Pb \text{ and } {}^{210}Po \qquad (1)$$

As mentioned above, the ^{222}Rn concentration in ordinary NG is 1-10 pCi/l, which corresponds to the ^{210}Pb and ^{210}Po release rates of 1-10 mCi/y, but in some American and Canadian NG the ^{222}Rn concentration is 100-1000 pCi/l, in which case the release rates are 100-1000 mCi/y.

These values should be compared with the ^{210}Pb and ^{210}Po release rates from a 1000 MW coal-fired power plant, which is usually of the order of several tens of mCi/y. Therefore, one can see that, while the release rates of an NG power plant using ordinary NG are much lower than those of a coal-fired power plant, when American or Canadian NG is used, they are higher.

It should also be kept in mind that the conversion formula of (1) is obtained assuming that ^{210}Pb and ^{210}Po in an NG well is removed almost completely. Since they are in equilibrium with ^{222}Rn, if they completely remain, the above estimate could be increased by $(4.7 \times 10^{-4})^{-1} \approx 2100$ times. Thus even if only 0.1% of ^{210}Pb and ^{210}Po in the well remain, they would increase the total release rates by about a factor 3. Hence the above estimate based on the assumption of complete removal of ^{210}Pb and ^{210}Po in the NG well is rather conservative.

These considerations show that the radiological impact of an NG power plant using American or Canadian NG could be considerable, although it has been completely overlooked so far.

3. DOSE DUE TO LEAFY VEGETABLES AND SEAFOODS

In the following the ^{222}Rn concentration in NG is assumed to be 100 pCi/l, which corresponds to the release rates of ^{210}Pb and ^{210}Po of 100 mCi/y.

The estimate of the dose through the pathway of leafy vegetables and seafoods was already given in the case of a coal-fired power plant in ref. 2. These values were somewhat revised in the later calculation (5). In both the papers the intake of ^{210}Pb is assumed to be 12 pCi/d. That of ^{210}Po is assumed 40 pCi/d in ref. 2, and 12-40 pCi/d in ref. 5. These values are based on the data by Takata et al. (6) and Okabayashi et al. (7). It was later found that 40 pCi/d was an overestimate and 12 pCi/d is appropriate for ^{210}Po also.

However, recently new measurement of ^{210}Pb were made (3), according to which the ^{210}Pb intake appears to be lower than the above value by about one order of magnitude. Since there are still uncertainties, in the following calculations the 12 pCi/d is assumed both for ^{210}Pb and ^{210}Po, keeping in mind that when the new data are used, the calculated values could be reduced by one order.

Then the same calculation as in refs. 2 or 5 is repeated. The results for the individual dose are given in Table 1. Although much smaller than natural background, the calculated dose is comparable to that of a nuclear or a coal-fired power plant.

Table 1. Maximum individual dose due to contamination of leafy vegetables and seafoods by a 1000 MW natural gas power plant (mrem/y)

Organ	Leafy vegetables	Seafoods	Total
skelton	1.63	5.70	7.33
gonads	0.29	0.97	1.26
breasts	0.09	0.32	0.41
lungs	0.26	0.86	1.12
thyroid gland	0.26	0.86	1.12
liver	0.74	2.60	3.34
kidney	0.63	2.20	2.83
lymph nodes	0.29	0.97	1.26
pancrea	0.14	0.55	0.69
spleen	0.14	0.51	0.69
whole body	0.49	1.69	2.18

As stated in the above discussion, when the new data on ^{210}Pb (3) are used, the dose is reduced by one order of magnitude, but even in this case if the ^{222}Rn concentration in NG is higher than 100 pCi/l, or if ^{210}Pb or ^{210}Po in the NG well is not completely removed, the dose could again be the same as Table 1.

4. CHROMOSOME ABERRATION

In the above calculation the quality factor (QF) of an α particle is assumed to be 20. However recent data suggest that the relative biological effectiveness (RBE) of α vs. β or γ can be much higher. Especially in the case of chromosome aberration RBE of as high as almost 300 has been reported for α vs. γ. For dicentrics the dose response relations are given by (8)

$$Y = 1.76 \times 10^{-4} X + 2.97 \times 10^{-6} X^2 \quad \text{for } ^{60}Co\ \gamma \qquad (2)$$

$$Y = 4.90 \times 10^{-2} X \quad \text{for } ^{241}Am \qquad (3)$$

where Y is dicentrics per cell and X is the dose in rad.

Since the natural occurrence of dicentrics in 30's or 40's is 0.05% (9), the doubling dose is about 3 rad for γ, but is as low as 10 mrad for α, thus giving RBE $\approx$ 300.

A crude estimate of the effect on chromosome aberration of the population near an NG power plant can be made as follows. The release rates of ^{210}Pb and ^{210}Po are assumed to be 100 mCi/y each, as before. For the dose estimate Camplin's calculation (10) is used with the following corrections.

First his assumption of the release rates is 2.0×10^9 Bq/y = 54 mCi/y, and so to convert it to the above value his results must be multiplied by 2. Moreover in his calculation QF = 20 is assumed, and so to convert it to RBE $\approx$ 300 his results must further be multiplied by 15. On the other hand Camplin's results on the dose due to ^{210}Pb and ^{210}Po are strongly criticized by Corbett (11), who claims that they are overestimated by at least a factor 10. Therefore the reduction of factor 20 is tentatively assumed. Since his results of the maximum individual dose is 23 mrem/y, the value corrected for chromosome aberration in terms of β or γ is:

$$23 \text{ mrem/y} \times 2 \times 15/20 = 34.5 \text{ mrem/y} \qquad (4)$$

Therefore, in the plant life of 30 years the accumulated dose is about 1 rem, and from the doubling dose of 3 rem mentioned above the expected increase of dicentrics is 30% or less (note that during the 30 years the person becomes older and the natural occurrence becomes higher), and so it is unlikely to be observable.

However, as mentioned before, if an NG that contains ^{222}Rn of several hundred pCi/l is used, or the ^{210}Pb and ^{210}Po removal in the well is not complete, the release rates of ^{210}Pb and ^{210}Po are higher, chromosome aberration may become observable.

5. CONCLUSION

An NG power plant using American or Canadian NG could be a significant radioactive polluting source. Especially the effect on chromosome aberration in the population near the power plant can be considerable, and in the extreme case the effect could reach the observable level. Since the radioactive contamination by an NG power plant has been completely overlooked, due care must be taken in the future.

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