EXPERIMENTAL LONG-TERM EXPOSURES OF FISH TO LOW DOSE RATE GAMMA- OR ALPHA-RADIATION

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Introduction

- The development of standards to protect environmental organisms from radiation requires data on the absorbed radiation dose rates received by them and on the relationship between the dose rates and damaging effects to the organisms.
- In the environment organisms may be exposed to radiation of different qualities (α-, β- and γ-radiation) and in order to assess combined, biologically effective, absorbed radiation dose rates, comparative factors for the relative damaging effects of the different radiation qualities are required.
- The lack of data necessary for the estimation of these comparative factors represents a key area where further research is required. No data are available for the relative damaging effects of α- and γ-radiation on aquatic organisms.
- This study has attempted to examine the comparative damaging effects of long-term exposures to α- or γ-radiation on a representative fish, the zebrafish (*Danio rerio*). Reproductive endpoints were studied as they are highly relevant to survival at the population level.

Methods

Groups of zebrafish were exposed to α-radiation from a young age by being fed brine shrimp (*Artemia salina*) which had been spiked with the α-emitter ^{210}Po. Other groups of fish were exposed to γ-radiation from external ^{137}Cs sources. The meal activities required to deliver the experimental α-radiation dose rates were determined in pilot experiments, while γ-radiation dose rates were measured by thermoluminescent dosimeters placed in fish tanks. The experimental dose rates are given in Table 1. The α-radiation dose rates given are estimates made using whole body concentrations of ^{210}Po in fish at termination of the experiment. The two higher dose rates (84 and 214μGy/h) are lower than those intended (185 and 740μGy/h, respectively) due to a failure of predictions from pilot experiments to hold for the long-term main experiment.

Irradiations with α- or γ-rays started at the same time, when fish were large enough to eat the ^{210}Po - spiked brine shrimps, and continued throughout the experiment. When mature, fish were placed in pairs and allowed to breed once per week for a period of approximately 1 year. Except for irradiation all fish, including unirradiated controls, were treated in the same way.

Table 1: The dose rates received by the different experimental groups of γ-irradiated and α-irradiated zebrafish

Experimental Group	1	2	3	4
γ-radiation dose rate (μGy/h)	300	1000	7400	
α-radiation dose rate. (μGy/h)	9.6	19	84	214

Experimental fish tank containing a pair of zebrafish separated by a perspex divider which is removed once a week to allow mating.

Results

For each pair the total number of eggs (all-eggs = fertile and unfertile combined) laid during the experiment was divided by the total number of lay opportunities (including those when no eggs were laid) to obtain the **mean number of all-eggs per lay opportunity**. The total number of eggs was also divided by the number of lay opportunites at which one or more eggs were laid to give **mean number of all-eggs per *used* lay opportunity**. In the same way fertile eggs (those viable 24 hours post-lay) were analysed to obtain **mean number of fertile eggs per lay opportunity** and **mean number of fertile eggs per *used* lay opportunity**.

Only γ-radiation Group 3 which received the highest radiation dose rate of 7400μGy/h showed significant effects. The mean numbers of all-eggs and of fertile eggs per lay opportunity in this group were significantly lower than in all others ($P<0.05$, Figure 1). The reason for this is that by lay opportunity 20 all pairs in γ-radiation Group 3 had ceased laying. The mean numbers of all-eggs and of fertile eggs per *used* lay opportunity were also significantly lower in γ-radiation Group 3 ($P<0.05$, Figure 2). The reduction in all-eggs was less marked than for fertile eggs indicating that when egg laying did occur smaller clutches were produced and they had a decreased proportion of fertile eggs.

A high percentage of fertile eggs in all groups subsequently hatched successfully (Table 2), with no significant radiation effects observed.

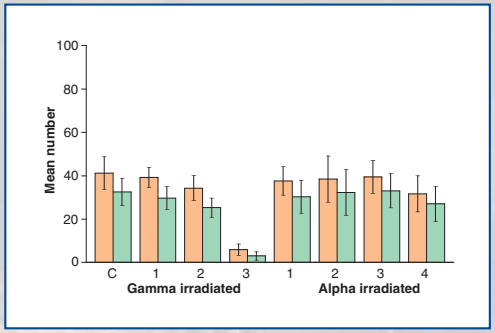

Figure 1: The mean number of all-eggs (orange columns) or fertile eggs (green columns) per lay opportunity (including those where no eggs were laid). Error bars are 95% confidence levels.

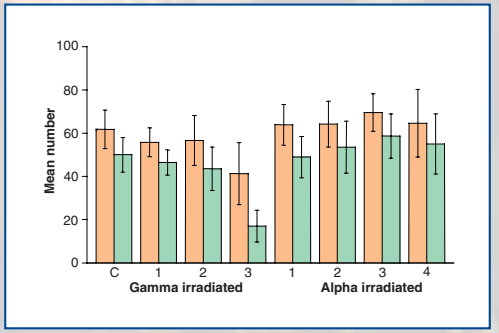

*Figure 2: The mean number of all-eggs (orange columns) or fertile eggs (green columns) per **used** lay opportunity (excluding those where no eggs were laid). Error bars are 95% confidence levels*

Table 2: The mean percentage of fertile eggs hatching successfully (± standard deviation)

Group	Dose rate (μGy/h)	Mean % of fertilised eggs hatching
Controls		**98.0 ± 8.5**
α-radiation		
1	9.6	96.3 ± 12.3
2	19	94.1 ± 12.9
3	84	98.4 ± 3.2
4	214	99.4 ± 2.3
γ-radiation		
1	300	98.2 ± 3.7
2	1000	93.4 ±19.1
3	7400	86.0 ± 19.4

Conclusions

Chronic exposure of zebrafish to γ-radiation at a dose rate of 7400μGy/h caused complete cessation of egg laying, while in fish exposed to lower dose rates of 1000μGy/h and 300μGy/h egg production was not significantly different from unirradiated controls.

Zebrafish exposed chronically to α-radiation, showed no significant effects on egg production, even at 214μGy/h, the highest used. In view of this it is only possible to estimate an upper limit of RBE_α for the endpoint of ceased egg production, $RBE_\alpha<35$ (ie 7400μGyh^{-1} / 214μGyh^{-1}).

In the 214μGy/h α-dose rate group, ovary activity concentrations of ^{210}Po were greater than those for whole body but varied greatly. The range of dose rates to the ovary estimated from these was 376μGy/h - 1045μGy/h. RBE_αs derived by comparison with the fish γ-irradiated at 7400μGy/h were $RBE_\alpha< 20$ to $RBE_\alpha< 7.1$. Thus the $RBE_\alpha< 35$ seems likely to be a conservative upper limit.

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