Radiation Monitoring

General requirements and principles

Radiation monitoring is necessary to indicate whether levels of background radiation are satisfactory for work with ionising radiation to proceed, and also to establish whether contamination of the work area has occurred. Further, it helps to establish the adequacy of current working methods, monitoring frequencies, Systems of Work, etc and, *inter alia,* any deficiences or breakdowns in such processes.

Systematic monitoring for external radiation and surface contamination needs to take place both within and outside Controlled and Supervised Areas. Monitoring equipment used for determining dose-rates must be registered with the Radiation Safety Unit and recalibrated annually by a qualified laboratory (e.g. Public Health England, PHE). This must also be undertaken if equipment has been repaired or modified in any way. The Radiation Safety Unit will arrange this. The results of all such monitoring and equipment calibration must be recorded and kept for at least two years.

Area monitoring programmes and schedules should be devised so as to be suitable for the needs of individual Schools, and must be clearly specified in the area Local Rules. This specification should include details of:

- type of measurements required (e.g. surface contamination, dose rate, air concentration);
- type of instrument;
- techniques to be used (e.g. direct measurement or wipe test);
- individuals responsible for measurements;
- records to be kept;
- actions to be taken if limits are exceeded.

External Radiation Monitoring

Radiation monitoring is required when there is a potential external radiation hazard from work with penetrating radiations such as gamma emitters, X-rays, or MBq quantities of beta emitters with a maximum energy > 0.3 MeV. **Controlled** or **Supervised Areas** may need to be designated if the likely dose rates exceed the values of 3 $\mu Sv.h^{-1}$ or 1 $\mu Sv.h^{-1}$ respectively for such areas.

Contamination Monitoring

Any area in which work with an unsealed source of radioactivity is undertaken must be regularly and systematically monitored both to check for surface contamination and, when detected, to confirm its removal after appropriate decontamination measures. The results of such monitoring, which must include working surfaces, floors and equipment must be recorded, even if no contamination is found. In addition to routine monitoring, additional monitoring must be undertaken (i) if any dispersal of radioactivity is suspected, and (ii) prior to any maintenance work being carried out on fume cupboards, ventilation systems and drains etc.

Hands, protective and personal clothing (including shoes) must always be monitored for potential contamination before leaving a Controlled or Supervised Area. If there is any reason to suspect that the face or any other skin areas may have been contaminated, these areas should also be monitored.

For surfaces inside fume cupboards and enclosed work stations (e.g. beta-boxes) in Controlled Areas, which are reserved solely for the handling of radioactive substances, contamination levels should be kept to the minimum reasonably achievable. The Health Protection Agency (HPA) recommends that measurement can be averaged over areas not greater than:

Body surfaces	1	cm^2
Floors, walls and ceilings	1000	cm^2
Other surfaces	300	cm^2

Contamination in ***all*** areas should be kept *as* ***low as reasonably achievable***. When checking for contamination, the monitor probe should be moved smoothly across the area at about 1 cm from the surface, allowing sufficient time for the detector to respond. If contamination is detected during monitoring, the area and/or skin must be decontaminated without delay. If surface contamination above the working limits persists, and cannot be removed by standard methods, the Radiation Safety Unit or relevant RPO

must be informed, as it may be necessary to temporarily designate a Controlled Area while decontamination is in progress. Details of appropriate decontamination procedures should be clearly displayed in the relevant work area.

Wherever practicable, direct monitoring should be used to determine contamination. However, in areas likely to be contaminated with tritium, or areas where the background rate from contained sources makes instrumental monitoring ineffective, **wipe testing** must be used. Unless other information is available it should be assumed that 10% of the contamination has been transferred to the wipe. [**N.B**. It is **not** possible to detect **tritium** contamination with any normal portable laboratory contamination monitor - **wipe tests must be used;** see note in Appendix].

Individual Schools are responsible for the provision of sufficient, suitable contamination and/or dose rate monitors (as appropriate), and must ensure that such equipment is available at all times when work with ionising radiation is in progress. The function of these instruments should be regularly checked using an appropriate check source. A battery check should also be performed prior to each period of use. Advice on suitable instruments is available from the Radiation Safety Unit, who should also be consulted before any new instruments are purchased by university Schools.

Radiation Monitoring of Designated Areas

General Requirements and Principles

All areas where radioactive materials are stored or handled must be regularly and appropriately monitored at intervals specified in the relevant Local Rules. The RPS must agree appropriate arrangements with the RPO to implement such monitoring. Records of monitoring must be kept for possible inspection by the Environment Agency inspectorate. All monitoring equipment must be registered by the RPO and recalibrated by a qualified laboratory on an annual basis, or following repair or modification. The results of all such monitoring and equipment calibration must be recorded and kept for at least two years.

Individual Schools are responsible for the provision of sufficient, suitable contamination and/or dose rate monitors (as appropriate), in order to ensure that such equipment is available at all times when work with ionising radiation is in progress. Advice on suitable instruments is available from Radiation Safety Unit staff, who must be consulted before any new instruments are purchased.

Contamination Control - Selecting A Monitoring Instrument

Mini-instruments Type 42

This instrument is only suitable for ^{125}I area monitoring, although it will detect the presence of other gamma and X-ray emitting radioisotopes and the bremsstrahlung radiation from higher energy beta emitters. A type 44 instrument must be used for other gamma emitters. The Area Contamination figures show typical instrument responses, as supplied by manufacturer. Responses to Point Sources are derived approximations.

Use the Area values to record measures of contamination as Bq.cm^{-2}. Point values may be used to estimate the activity on small articles of waste (blots, empty eppendorf tubes etc). Typical Background readings are: 2 – 10 cps. Higher readings may indicate contamination of the meter itself or proximity to stocks of radioisotopes.

In the tables below cps = number of counts per second (as read from the instrument) minus the background reading. Use the maximum reading obtained from a given area. All values given in the tables below assume a distance of 1cm between probe and source.

Table 1: Instrument Sensitivity

Isotope:	**^{125}I**
Sensitivity (cps/Bq.cm^{-2}):	**0.6**

Table 2: Area Monitoring

CPS	**Contamination (Bq.cm-2)**		
	^{125}I		
0	**0**		
1	**2**		
2	**3**		
3	**5**		
4	**7**		
5	**8**		
6	**10**		
7	**12**		
8	**13**		
9	**15**		
10	**17**		
15	**25**		
20	**33**		
30	**50**		
40	**67**		
50	**83**		
100	**167**		
150	**250**		
200	**333**		
300	**500**		
400	**667**		
500	**833**		
600	**1000**		
700	**1167**		
800	**1333**		
900	**1500**		
1000	**1667**		
1500	**2500**		
2000	**3333**		

Table 3: Point Source Response

CPS	Activity (kBq)		
	^{125}I		
0	0.000		
1	0.011		
2	0.022		
3	0.033		
4	0.044		
5	0.056		
6	0.067		
7	0.078		
8	0.089		
9	0.100		
10	0.111		
15	0.167		
20	0.222		
30	0.333		
40	0.444		
50	0.556		
100	1.111		
150	1.667		
200	2.222		
300	3.333		
400	4.444		
500	5.556		
600	6.667		
700	7.778		
800	8.889		
900	10.000		
1000	11.111		
1500	16.667		
2000	22.222		

= contamination (Bq.cm^{-2}) above **Working Limit** for **Inactive Areas**
= contamination (Bq.cm^{-2}) above **Working Limit** for **Active Areas**

Mini-instruments Type 44A

This instrument is suitable the detection of all gamma and X-ray emitting radionuclides (including ^{125}I, ^{51}Cr & ^{22}Na). It will also detect bremsstrahlung radiation from higher energy beta emitters but is NOT suitable for the area contamination monitoring of pure beta emitters The area Contamination figures show typical instrument responses for ^{125}I & ^{51}Cr, as supplied by the manufacturer. Users of other radioisotopes should contact the RPS for advice on instrument response. Responses to Point Sources are derived approximations.

Use the Area values to record measures of contamination as $Bq.cm^{-2}$. Point values may be used to estimate the activity on small articles of waste (blots, empty eppendorf tubes etc). Typical Background readings: 10 – 20 cps. Higher readings may indicate contamination of the meter itself or proximity to stocks of radioisotopes.

In the tables below CPS = number of counts per second (as read from the instrument) minus the background reading. Use the maximum reading obtained from a given area. All values given in the tables below assume a distance of 1cm between probe and source.

Table 1: Instrument Sensitivity

Isotope:	**^{51}Cr**	**^{125}I**	
Sensitivity (CPS/Bq.cm-2):	**0.06**	**3.8**	

Table 2: Area Monitoring

CPS	Contamination (Bq.cm-2)		
	^{51}Cr	**^{125}I**	
0	**0**	**0**	**0**
1	**17**	**0**	**0**
2	**33**	**1**	**1**
3	**50**	**1**	**1**
4	**67**	**1**	**1**
5	**83**	**1**	**1**
6	**100**	**2**	**2**
7	**117**	**2**	**2**
8	**133**	**2**	**2**
9	**150**	**2**	**2**
10	**167**	**3**	**3**
15	**250**	**4**	**4**
20	**333**	**5**	**5**
30	**500**	**8**	**8**
40	**667**	**11**	**10**
50	**833**	**13**	**13**
100	**1667**	**26**	**25**
150	**2500**	**39**	**38**
200	**3333**	**53**	**50**
300	**5000**	**79**	**75**
400	**6667**	**105**	**100**
500	**8333**	**132**	**125**
600	**10000**	**158**	**150**
700	**11667**	**184**	**175**
800	**13333**	**211**	**200**
900	**15000**	**237**	**225**
1000	**16667**	**263**	**250**
1500	**25000**	**395**	**375**
2000	**33333**	**526**	**500**

Table 3: Point Source Response

CPS	Activity (kBq)		
	^{51}Cr	^{125}I	
0	0.000	0.000	
1	0.189	0.003	
2	0.377	0.006	
3	0.566	0.009	
4	0.755	0.013	
5	0.943	0.016	
6	1.132	0.019	
7	1.321	0.022	
8	1.509	0.025	
9	1.698	0.028	
10	1.887	0.031	
15	2.830	0.047	
20	3.774	0.063	
30	5.660	0.094	
40	7.547	0.125	
50	9.434	0.156	
100	18.868	0.313	
150	28.302	0.469	
200	37.736	0.625	
300	56.604	0.938	
400	75.472	1.250	
500	94.340	1.563	
600	113.208	1.875	
700	132.075	2.188	
800	150.943	2.500	
900	169.811	2.813	
1000	188.679	3.125	
1500	283.019	4.688	
2000	377.358	6.250	

= contamination (Bq.cm-2) above **Working Limit** for **Inactive Areas**
= contamination (Bq.cm-2) above **Working Limit** for **Active Areas**

Mini-instruments Type E

This instrument is suitable for the detection of beta emitting radionuclides with E_{max} > 150keV (including ^{14}C, ^{35}S, ^{33}P & ^{32}P), but it will NOT detect ^{3}H contamination. Neither is it ideal for ^{14}C or ^{35}S monitoring due to its poor response at low E_{max}. Area Contamination figures show typical instrument responses, as supplied by manufacturer. Responses to Point Sources are derived approximations.

Use the Area values to record measures of contamination as $Bq.cm^{-2}$. Point values may be used to estimate the activity on small articles of waste (blots, empty eppendorf tubes etc). Typical Background readings:0.5 - 1.0 cps. Higher readings may indicate contamination of the meter itself or proximity to stocks of radioisotopes.

In the tables below cps = number of counts per second (as read from the instrument) minus the background reading. Use the maximum reading obtained from a given area. All values given in the tables below assume a distance of 1cm between probe and source.

Table 1: Instrument Sensitivity

Isotope:	**$^{14}C/^{35}S$**	**$^{33}P/^{45}Ca$**	**^{32}P**
Sensitivity (CPS/Bq.cm-2):	**0.6**	**1.0**	**1.7**

Table 2: Area Monitoring

CPS	**Contamination (Bq.cm-2)**		
	$^{14}C/^{35}S$	**$^{33}P/^{45}Ca$**	**^{32}P**
0	**0**	**0**	**0**
1	**2**	**1**	**1**
2	**3**	**2**	**1**
3	**5**	**3**	**2**
4	**7**	**4**	**2**
5	**8**	**5**	**3**
6	**10**	**6**	**4**
7	**12**	**7**	**4**
8	**13**	**8**	**5**
9	**15**	**9**	**5**
10	**17**	**10**	**6**
15	**25**	**15**	**9**
20	**33**	**20**	**12**
30	**50**	**30**	**18**
40	**67**	**40**	**24**
50	**83**	**50**	**29**
100	**167**	**100**	**59**
150	**250**	**150**	**88**
200	**333**	**200**	**118**
300	**500**	**300**	**176**
400	**667**	**400**	**235**
500	**833**	**500**	**294**
600	**1000**	**600**	**353**
700	**1167**	**700**	**412**
800	**1333**	**800**	**471**
900	**1500**	**900**	**529**
1000	**1667**	**1000**	**588**
1500	**2500**	**1500**	**882**
2000	**3333**	**2000**	**1176**

Table 3: Point Source Response

CPS	**Activity (kBq)**		
	$^{14}C/^{35}S$	$^{33}P/^{45}Ca$	^{32}P
0	0.000	0.000	0.000
1	0.017	0.010	0.008
2	0.033	0.020	0.017
3	0.050	0.030	0.025
4	0.067	0.040	0.033
5	0.083	0.050	0.042
6	0.100	0.060	0.050
7	0.117	0.070	0.058
8	0.133	0.080	0.067
9	0.150	0.090	0.075
10	0.167	0.100	0.083
15	0.250	0.150	0.125
20	0.333	0.200	0.167
30	0.500	0.300	0.250
40	0.667	0.400	0.333
50	0.833	0.500	0.417
100	1.667	1.000	0.833
150	2.500	1.500	1.250
200	3.333	2.000	1.667
300	5.000	3.000	2.500
400	6.667	4.000	3.333
500	8.333	5.000	4.167
600	10.000	6.000	5.000
700	11.667	7.000	5.833
800	13.333	8.000	6.667
900	15.000	9.000	7.500
1000	16.667	10.000	8.333
1500	25.000	15.000	12.500
2000	33.333	20.000	16.667

= contamination (Bq.cm-2) above **Working Limit** for **Inactive Areas**

= contamination (Bq.cm-2) above **Working Limit** for **Active Areas**

Mini-instruments Type EL

It is suitable for the detection of beta emitting radionuclides with Emax > 150keV (including ^{14}C, ^{35}S, ^{33}P & ^{32}P), but it will NOT detect ^{3}H contamination. Area Contamination figures show typical instrument responses, as supplied by manufacturer. Responses to Point Sources are derived approximations.

Use the Area values to record measures of contamination as $Bq.cm^{-2}$. Point values may be used to estimate the activity on small articles of waste (blots, empty eppendorf tubes etc). Typical Background readings: 0.5 - 2.0 cps. Higher readings may indicate contamination of the meter itself or proximity to stocks of radioisotopes.

In the tables below CPS = number of counts per second (as read from the instrument) minus the background reading. Use the maximum reading obtained from a given area. All values given in the tables below assume a distance of 1cm between probe and source.

Table 1: Instrument Sensitivity

Isotope:	**$^{14}C/^{35}S$**	**$^{33}P/^{45}Ca$**	**^{32}P**
Sensitivity (CPS/Bq.cm-2):	**1.3**	**2.0**	**4.8**

Table 2: Area Monitoring

CPS	**Contamination (Bq.cm-2)**		
	$^{14}C/^{35}S$	**$^{33}P/^{45}Ca$**	**^{32}P**
0	**0**	**0**	**0**
1	**1**	**1**	**0**
2	**2**	**1**	**0**
3	**2**	**2**	**1**
4	**3**	**2**	**1**
5	**4**	**3**	**1**
6	**5**	**3**	**1**
7	**5**	**4**	**1**
8	**6**	**4**	**2**
9	**7**	**5**	**2**
10	**8**	**5**	**2**
15	**12**	**8**	**3**
20	**15**	**10**	**4**
30	**23**	**15**	**6**
40	**31**	**20**	**8**
50	**38**	**25**	**10**
100	**77**	**50**	**21**
150	**115**	**75**	**31**
200	**154**	**100**	**42**
300	**231**	**150**	**63**
400	**308**	**200**	**83**
500	**385**	**250**	**104**
600	**462**	**300**	**125**
700	**538**	**350**	**146**
800	**615**	**400**	**167**
900	**692**	**450**	**188**
1000	**769**	**500**	**208**
1500	**1154**	**750**	**313**
2000	**1538**	**1000**	**417**

Table 3: Point Source Response

CPS	Activity (kBq)		
	$^{14}C/^{35}S$	$^{33}P/^{45}Ca$	^{32}P
0	0.000	0.000	0.000
1	0.010	0.007	0.005
2	0.020	0.013	0.010
3	0.030	0.020	0.015
4	0.040	0.027	0.020
5	0.050	0.033	0.025
6	0.060	0.040	0.030
7	0.070	0.047	0.035
8	0.080	0.053	0.040
9	0.090	0.060	0.045
10	0.100	0.067	0.050
15	0.150	0.100	0.075
20	0.200	0.133	0.100
30	0.300	0.200	0.150
40	0.400	0.267	0.200
50	0.500	0.333	0.250
100	1.000	0.667	0.500
150	1.500	1.000	0.750
200	2.000	1.333	1.000
300	3.000	2.000	1.500
400	4.000	2.667	2.000
500	5.000	3.333	2.500
600	6.000	4.000	3.000
700	7.000	4.667	3.500
800	8.000	5.333	4.000
900	9.000	6.000	4.500
1000	10.000	6.667	5.000
1500	15.000	10.000	7.500
2000	20.000	13.333	10.000

= contamination (Bq.cm-2) above **Working Limit** for **Inactive Areas**
= contamination (Bq.cm-2) above **Working Limit** for **Active Areas**

Mini-instruments Type EP15

Suitable for the detection of beta emitting radionuclides with Emax > 150keV (including ^{14}C, ^{35}S, ^{33}P & ^{32}P), but it will NOT detect ^{3}H contamination. Area Contamination figures show typical instrument responses, as supplied by manufacturer. Responses to Point Sources are derived approximations.

Use the Area values to record measures of contamination as $Bq.cm^{-2}$. Point values may be used to estimate the activity on small articles of waste (blots, empty eppendorf tubes etc): Typical Background readings: 0.5 - 2.0 CPS. Higher readings may indicate contamination of the meter itself or proximity to stocks of radioisotopes.

In the tables below CPS = number of counts per second (as read from the instrument) minus the background reading. Use the maximum reading obtained from a given area.

All values given in the tables below assume a distance of 1cm between probe and source.

Table 1: Instrument Sensitivity

Isotope:	**$^{14}C/^{35}S$**	**$^{33}P/^{45}Ca$**	**^{32}P**
Sensitivity (CPS/Bq.cm-2):	**1.3**	**1.7**	**4.0**

Table 2: Area Monitoring

CPS	**Contamination (Bq.cm-2)**		
	$^{14}C/^{35}S$	**$^{33}P/^{45}Ca$**	**^{32}P**
0	**0**	**0**	**0**
1	**1**	**1**	**0**
2	**2**	**1**	**1**
3	**2**	**2**	**1**
4	**3**	**2**	**1**
5	**4**	**3**	**1**
6	**5**	**4**	**2**
7	**5**	**4**	**2**
8	**6**	**5**	**2**
9	**7**	**5**	**2**
10	**8**	**6**	**3**
15	**12**	**9**	**4**
20	**15**	**12**	**5**
30	**23**	**18**	**8**
40	**31**	**24**	**10**
50	**38**	**29**	**13**
100	**77**	**59**	**25**
150	**115**	**88**	**38**
200	**154**	**118**	**50**
300	**231**	**176**	**75**
400	**308**	**235**	**100**
500	**385**	**294**	**125**
600	**462**	**353**	**150**
700	**538**	**412**	**175**
800	**615**	**471**	**200**
900	**692**	**529**	**225**
1000	**769**	**588**	**250**
1500	**1154**	**882**	**375**
2000	**1538**	**1176**	**500**

Table 3: Point Source Response

CPS	Activity (kBq)		
	$^{14}C/^{35}S$	$^{33}P/^{45}Ca$	^{32}P
0	0.000	0.000	0.000
1	0.010	0.007	0.005
2	0.020	0.013	0.010
3	0.030	0.020	0.015
4	0.040	0.027	0.020
5	0.050	0.033	0.025
6	0.060	0.040	0.030
7	0.070	0.047	0.035
8	0.080	0.053	0.040
9	0.090	0.060	0.045
10	0.100	0.067	0.050
15	0.150	0.100	0.075
20	0.200	0.133	0.100
30	0.300	0.200	0.150
40	0.400	0.267	0.200
50	0.500	0.333	0.250
100	1.000	0.667	0.500
150	1.500	1.000	0.750
200	2.000	1.333	1.000
300	3.000	2.000	1.500
400	4.000	2.667	2.000
500	5.000	3.333	2.500
600	6.000	4.000	3.000
700	7.000	4.667	3.500
800	8.000	5.333	4.000
900	9.000	6.000	4.500
1000	10.000	6.667	5.000
1500	15.000	10.000	7.500
2000	20.000	13.333	10.000

= contamination (Bq.cm-2) above **Working Limit** for **Inactive Areas**

= contamination (Bq.cm-2) above **Working Limit** for **Active Areas**

Tritium Contamination Monitoring by Wipe Testing

General

As will be evident from the notes above, tritium contamination cannot be detected with any hand-held instrument, and "wipe tests" are therefore necessary. In laboratories not equipped with hand-held monitors, other isotopes may also be monitored *via* this method (e.g. ^{14}C) by selecting an appropriate programme on the scintillation counter. Note that in each series of wipes an uncontaminated sample should be counted as a control in order to obtain a "background" count.

Active Area Monitoring

All areas where unsealed sources of ^{3}H are used ("active areas") must be monitored both before and after each work session. The term "area", in this instance, also includes any equipment that could have been contaminated (e.g. centrifuges, hybridisation ovens, and heating blocks). Wipes taken prior to starting work will indicate whether any contamination was left by a previous user.

If an area is found to be contaminated prior to undertaking work, the RPS must be informed and the incident investigated. Minor spills or splashes which occur during an experiment should be cleaned up by the user in accordance with the Local Rules. If it proves possible to remove the contamination, the Radiation Safety Unit (south campus only) or relevant RPO should be contacted for advice. Following the monitoring procedure, all contamination measurements must be recorded (as Bq/cm^2).

Laboratory Monitoring

Once per month (or as otherwise decided, and stated in the Local Rules), the entire laboratory (including inactive areas) should be surveyed for contamination. Reference to a schematic diagram of the lab may be helpful in demarcating the areas to be surveyed, and those points at which wipe tests should be taken. All results should be recorded, and any levels of contamination should be reported to the RPS.

Procedure for Monitoring

1. Moisten a suitable wipe, such as a glass-fibre disc small enough to fit into a liquid scintillation vial, with water or other solvent in which the contamination is soluble.
2. Wipe a known area of surface, normally 100 or 1000 cm^2.
3. Place the wipe into a scintillation vial with 10 cm3 of liquid scintillant.
4. Count the activity in a liquid scintillation counter.
5. In the absence of any more accurate information assume that 10% of the activity on the wiped surface has been transferred to the wipe.
6. Calculate the contamination level using the formula:

$$\text{contamination level } (Bq.cm^{-2}) = \frac{C}{A} \times \frac{100}{Eff} \times \frac{100}{T}$$

where *C* = count-rate in cps, corrected for background
A = area wiped in cm2
Eff = percentage counting efficiency for isotope in question
T = percentage of contamination picked up (normally 10%)

Working Limits (Bq.cm^{-2})	**^{3}H**	**^{14}C**
Active Areas:	300	30
Inactive Areas:	30	3