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Best Available Techniques and Radiological Dose Assessment for the University of Essex

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1. Introduction and scope of report

To ensure compliance with the Basic Safety Standards Directive and the key principles of radiological protection, operators are required to ensure exposures from the creation and disposal of radioactive waste are optimised, kept as low as reasonably achievable and within the recommended dose limits. The techniques and measures that are used to achieve an optimised outcome are described as "best available techniques".

This document is a revision of the original "best practicable means assessment" published in June 2007, with further revisions on 16th February 2013 and 16th January 2018 and incorporates the Environment Agency recommendations to apply "best available techniques". Included in this report is a radiological assessment of doses resulting from the accumulation and disposal of radioactive waste to demonstrate compliance with the guidance and the recommended dose limits.

This report describes the control measures used by the University to demonstrate that it has examined the best available techniques employed for the use, accumulation and disposal of radionuclides to the environment. Concurrently, the report describes the policy, management systems, organisational structure and resources that are in place to ensure compliance with the requirements of the Permit (Ref. No. EPR/YB3135DR) issued by the Environment Agency currently regulated under the Environmental Permitting Regulations 2016.

This BAT assessment uses recent models, IRAT updated 04/05/2022 to ensure that wastes have been minimised and that permitted discharges of radioactive substances will be within dose constraints and limits for members of the public. These are IRAT 'Releases to Air' and Releases to Sewer'. These models also ensure that radioactive discharges do not affect the integrity of Natura 2000 habitat sites.

2. Description of Facility

The University of Essex is a campus based university with the main site located to the southeast of Colchester, just south of the road A133 and north of the River Colne. The University also has campuses at Southend and Loughton, however work with ionising radiation does not take place at these sites.

It uses small quantities of radionuclides in the teaching and research laboratories in the Department of Life Sciences, situated in the Life Sciences Building in the centre of the Colchester campus.

3. Management of radioactive substances

The management of radioactive substances and radiation protection is described in the Health and Safety Policy, and the University Local Rules for Use of Ionising Radiation. These have had a cycle of review since the last BAT assessment (June 2022). These are freely available on the University website.

Ultimate responsibility for ensuring compliance with the legal requirements for health and safety rests upon the University as a chartered body. This responsibility is discharged through policies and standards decided upon by the University Council and University Steering Group (USG), after considering the recommendations of the Health and Safety Group, which is a sub-group of USG.

Executive responsibility is delegated to the Vice Chancellor as Chief Executive. He/she is having overall accountability for health and safety at the University. An organisation chart giving details of the safety reporting structure can be found in the University Health and Safety Policy on the University website.

The University has appointed an external company, RPA Plus to act as the University's appointed Radiation Protection Adviser (RPA) and Radioactive Waste Adviser (RWA). Specifically, Niall Higbee as lead RPA/RWA with Mike Bone as Deputy RPA, to provide technical expertise and advice on matters relating to radiological protection and in the case of Niall Higbee radioactive waste disposal. All contractors providing training are required to provide a training course that includes an understanding of BAT and how to comply with BAT and the University Local Rules that achieve BAT.

Day to day operations are overseen and supported by the University's Workplace Health, Safety and Wellbeing service , one of whom also acts as the University Ionising Radiation Protection Officer (UIRPO).

The UIRPO is a member of the University Health and Safety Group (HSG) and Chairs the Ionising Radiation Protection Sub-Group, a sub-group of HSG. The Health and Safety Group is chaired by the Director of People and Culture. The RPA/RWA is a member of the Ionising Radiation Protection Sub-Group.

4. Management of radioactive substances within departments

The University Heads of Department have executive responsibility for ensuring the health and safety of personnel under their control and appoint Departmental Ionising Radiation Protection Supervisors (DIRPSs) to ensure compliance with local rules relating to work with sources of ionising radiations. DIRPSs are trained by relevant organisations, e.g., RPA Plus, Stephen Green and Associates Ltd. and UKHSA. The HSE recommends that refresher training is delivered at intervals of three to five years. The University's Local Rules (Section 3: Registered Radiation Workers) require that anyone who undertakes formal training on the safe use of radiation, must undergo refresher training at least every 5 years. In addition, in-house, documented training of all staff who work with sources of ionising radiation is undertaken. An important part of training is to minimise radioactive waste and optimise the amounts of radioactivity used.

In line with university policy Heads of Department are required to prepare Departmental health and safety standards to ensure compliance with regulatory requirements.

5. University Arrangements for ensuring use of Best Available Techniques

5.1 Arrangements and techniques for handling radionuclides

The University uses a range of radionuclides, e.g., tritium, carbon-14 and occasionally other short-lived beta/gamma emitters, in the form of open sources.

No one may work with radionuclides unless they have been registered as "registered radiation workers". Students may work with radionuclides providing they are subject to supervision by an appropriate academic and work under a written scheme of work. Any registrations are approved by the UIRPO who maintains a record of who is registered (Radiation Workers Registration (Form 1)).
All registered radiation workers must demonstrate that they are familiar with the University's local rules. They must receive appropriate training prior to commencing work with radionuclides. The DIRPS will also satisfy themselves that the person appears to be competent to carry out the work. The person receiving training will sign a statement to the effect that they have received training (Radiation Workers Training Record, Form 3) and this will be countersigned by the DIRPS.

Visiting academics and research staff working with radionuclides are also required to register (using the Visiting Radiation Workers Registration (Form 2)) and will either be required to provide evidence of training by another institution or work under the supervision of a competent radiation worker. Any approval is at the discretion of the UIRPO.

All work with radionuclides must be supported by an approved scheme of work (Form 4). Details are given in the Local Rules, Section 4. To ensure best available techniques are used, as part of the scheme of work, personnel must justify the use of radionuclides in preference to other techniques, minimise the quantity used and consider techniques in order to minimise the waste generated. Disposal strategies and disposal route must also be identified as part of the scheme of work. The form detailing the approved scheme of work incorporates a section where the applicant must provide a justification and detail how they will optimise their work and the disposals. All work with radionuclides carried out under an approved scheme of work is reviewed and countersigned by the DIRPS and the UIRPO prior to commencing work. The UIRPO seeks the advice of the University's RPA/RWA prior to giving approval.

Procurement of radionuclides is strictly controlled. The route for procurement of radioactive materials is detailed in the flow diagram in Fig. 1. Only scheme holders and workers identified on the scheme are permitted to order radionuclides. Radiation scheme holders can only order or receive gifts of isotopes for a scheme of work that has been approved by the DIRPS and UIRPO. The Finance Officer will confirm this before allowing the order to go through.

Closed sources can only be ordered for an approved scheme of work. All requests must be submitted to the DIRPS for checking and recording and then signed by the Head of Department. The Department must receive written approval from the UIRPO before ordering a closed source or receiving a gift of a closed source. Departments are required to provide evidence that funding is available for safe disposal of the source at the end of its working life.

5.2 Minimising the production of waste

Prior to using radionuclides, a scheme of work must have been produced. As part of this personnel must identify the production of waste products and identify the quantity and waste disposal streams, including aqueous and atmospheric discharges.

They are also encouraged to order the minimum quantity for the experiment to ensure the waste is minimised. They should seek suppliers who can supply the actual quantity of stock solution required.

Personnel are required not to generate waste via contamination and to consider equipment such as trays to minimise spills and cross contamination. Wherever possible they are encouraged to use the very low level waste route or delay and decay.

Personnel are to monitor their workplace on a routine basis to ensure cross contamination of equipment and surroundings does not occur, this is to minimise contaminated waste, to be disposed of, when facilities are decommissioned at a future date.

Any waste accumulated and sent for disposal is assessed to ensure that the quantity does not exceed any limits laid down in the Environment Agency Permit for the accumulation and disposal of radioactive material.

The scheme of work is reviewed by the DIRPS and by the UIRPO and RPA/RWA

5.3 Release Routes

The release routes are identified in the flow diagram Fig.2. The main disposal routes are gases via atmospheric dispersion from Stack 9 (although Stack 8,9 &12 are permitted in Schedule 3 of the Permit), aqueous waste via the mains drainage system to sewer and ultimately to the sewage works. Other waste streams include very low level solid waste to landfill and organic liquids and low level solid waste via a waste contractor for incineration.

Radiological doses via these routes have been calculated and are to be found in the assessment in Appendix 1.

5.4 Abatement

As quantities of radioactive materials released to the environment, by air or aqueous discharge are relatively small, no form of abatement is used as the cost of implementing any form of abatement would be disproportionate to the benefits in terms of dose reduction.

Disposal to air: Only 250 MBq of carbon-14 is specified. Other releases are only adventitious.

Disposal as aqueous waste; Only 200 MBq of the following are specified; tritium, carbon-14, phosphorous-32 and any other radionuclide exempt alpha emitters.

5.5 Decay Storage

Note: alphas waste not permitted.

Decay storage is used as a means of reducing discharges to the environment, and so is the Best Achievable Techniques particularly for waste containing short lived radionuclides such as Phosphorus-32.

This is appropriate for short lived isotopes as the majority have decayed by the time the material is sent for disposal. The maximum permitted accumulation period is 365 days for solid and organic liquid waste. Note: alphas waste not permitted.

5.6 Assessment of disposals

The quantities of material sent for disposal are calculated from the usage of material. In-house designed software in the form of a database is used to record usage of material. Users are required to submit their usage/disposal records to the UIRPO on a monthly basis as detailed in Section 6 of the local rules.

5.7 Potential for unintentional release

There are several potential routes for unintended releases. These are identified as:

a. accidental release via the fume cupboard
b. accidental spillage via the drainage system
c. major fire in the laboratory

An assessment has shown that quantities of materials used at any one time would not breach the Permit limits, so an unintended release of significant quantities is unlikely.

The most likely unintended release would be if there was a major fire in the laboratory or storage facility. Doses to the public as a result of this type of release have been calculated in the radiological assessment.

Waste and new stocks are stored separately which would reduce the possibility of a large single release of the total inventory unless the building was subject to a major fire and razed to the ground.

The facilities all have fire detection systems, which would alert staff to a fire who will then call the Fire and Rescue Service. The Fire and Rescue Service will normally respond within 5 minutes.

5.8 Review Period

This assessment will be reviewed if there are any significant operational changes to ensure compliance with the Environment Agency requirements in the Permit. In any event the assessment will be reviewed at least every 5 years.

5.9 Maintenance

Equipment and services are subject to routine maintenance to ensure they are functioning correctly. All fume hoods within Life Sciences receive a thorough examination (which includes functional checks) at least every 14 months, as required under the Control of Substances Hazardous to Health (COSHH) Regulations 2002 (tables revised 17th January 2020).

Records of maintenance are maintained by the University Estate Management Section, with copies held by Life Sciences.

6. Comparison of available techniques to decide which is the Best Available Technique (while minimising dose to operators and taking account of time trouble and money).

Replacement of use of radiolabelled techniques with techniques that do not used radioactive material?

Generally, it is impractical to replace the radiolabelling techniques because these have been shown to give the most reliable data. It may not be possible to change technique for a succession of data arising over many years.

Many of the non-radiolabelling techniques use fluorescent compounds which may be more damaging to the environment than radiolabelled compounds.

Disposal routes-compared to find BAT.

These are as described, below. Alternative routes have been pursued only briefly because the quantities discharged are relatively low and the cost would not be proportionate to the benefits likely to be derived.

Options for each disposal stream would be:

Gaseous discharges: a. discharge to air via fume cupboards with filter
b. discharge to air via fume cupboards fitted with scrubber system

c. discharge to air – no filter

a Filters are used in fume cupboards for health and safety purposes, where dust is produced as part of the process, otherwise discharges in fume cupboards are straight to air. Using filters in all fume cupboards for radiological work would increase the solid waste generated. Given that discharges to air are below the reporting threshold for the Environment Agency Pollution Inventory Electronic Data Capture return, filters are not the best option considering BAT.

b Current fume cupboards do not have the facility for a scrubber system. If this was in place any gaseous discharges would effectively become aqueous discharges to drain. Scrubbers have been used in the past and the hard water in this area has hindered their performance (limescale and blockages). Current discharges to drain are below the reporting threshold for the Environment Agency Pollution Inventory Electronic Data Capture return. Additional aqueous discharges (derived from gaseous waste) would not increase the discharges to drain above this reporting level. However, there would be a cost to installing scrubber system so this is not the best option considering BAT.

Aqueous discharges: a. to drain via treatment plant (ion exchange, distillation, reverse osmosis?)
b.to drain via designated sink and controlled by RPSs.

a. **A treatment plant to remove activity would be an additional expense and would require investigation/resource to determine effectiveness.**
b. **Discharges to drain are low, and below the reporting threshold for the Environment Agency Pollution Inventory Electronic Data Capture return.**

Conclude that aqueous discharges to drain via designated sinks as supervised by the RPS are BAT.

Organic liquid discharges: a. use of biodegradable liquid scintillation fluid e.g., 'Prosafe'
b. transfer off site to appropriate company for incineration

a. **The RPS continues to review new biodegradable liquid scintillation fluid however so far none of them have been suitable for purpose.**
b. **If not biodegradable, liquid scintillation fluid cannot be disposed of to drain and only option is to incinerate.**

Options for vials are:
bi. Empty vial contents into carboy (for incineration) and dispose of VLLW
bii. Send vial plus contents for incineration

Dose to laboratory personnel

Dose from transfer of tritiated contaminated scintillant to carboy, assume no inhalation from opening carboy:

1% transferred to gloved hands, assume 1% absorbed through the skin via contaminated gloves emptying vials.
There is an increased risk in contamination and spillage due to lifting the carboy out of the cupboard, especially when it is fairly full. Scintillation fluid is toxic and the more handling there is the more chance of surface contamination and contamination of the skin of radiation workers. This is not only considered to be best practice but is not Best Available Technique (BAT).

Total Contents disposal via Incineration

On incineration at a commercial plant there will be a discharge via the stack, but this will have been part of the radiological assessment for the incinerator operator.

Advantage of incineration is the reduction of plastic going to land waste and conversion of plastic and contents to its basic elements, carbon and water. However, incinerating the vials will involve additional plastic waste bins for disposal and an increase in transport costs due to additional collections.

Organic liquid discharge: Conclusion
In the interests reducing risks/handling of opening vials, disposal of vial and contents via incineration would be the preferred option as this is higher up the waste hierarchy.

Conclusion; sending vials plus contents for incineration is BAT.

Solid waste under permit conditions or as VLLW:

a. The university has the option to use VLLW which is sent for incineration (or possibly to landfill. This route is not in current operation and requires the UIRPO's permission.
b. Solid waste under permit conditions is sent for incineration for energy recovery. This is higher up the waste hierarchy than landfill.

Conclusion (b) and is considered to be BAT.

7. Summary of assessment of usage of Best Available Techniques

The University achieves the application of best available techniques by:

- i) Management of the use of radioactive materials and the creation and disposal of waste;
- ii) Ensuring users handling radioactive material are registered and deemed competent;
- iii) Providing appropriate training for all users including visiting academics;
- iv) Controlling procurement of sources, ensuring use is justified and no alternative technique is available;
- v) Using an approved scheme of work to ensure BAT addressed;
- vi) Procuring the minimum required to avoid over stocking;
- vii) Routine monitoring to minimise contamination;
- viii) Restricting nearly all work to one laboratory;
- ix) Using delay and decay storage where appropriate;
- x) Minimising period waste is retained, unless delay and decay;
- xi) Maintenance of appropriate records, to ensure permit limits not breached;
- xii) Disposal of waste in a form to minimise effect on environment.

8 Summary of results of radiological assessment

The results from the radiological assessment indicate that for normal intended releases, doses to the public from the current authorised discharges are well within acceptable limits.

The maximum calculated dose to a member of the public from all sources, is for an fishing family mainly from eating fish from the estuary and coastal waters, this dose is 1.8 $\mu Sv.y^{-1}$. This is followed by a dose to anglers mainly from eating fish from the river Colne, this dose is 1.2 $\mu Sv.y^{-1}$.

This is based on very pessimistic assumptions as the calculations are based on the maximum permitted annual discharges which have never taken place.

The calculated dose to a member of the public as the result of a catastrophic fire would give rise to a dose to a member of the public 1.1 µSv with the food dose caused by the fire being 0.94 µSv.

The majority of doses are well below the Environment Agency threshold for optimisation of $20\mu Sv.y^{-1}$ and well below the Euratom dose constraint of 0.3mSv per site.

9. References

a. https://www.gov.uk/government/publications/radioactive-substances-regulation-rsr-objective-and-principles/radioactive-substances-regulation-rsr-objective-and-principlesadioactive Substances Regulation:

See Principle 8; Assessment of Best Available Techniques (BAT)

b. https://www.gov.uk/government/publications/initial-radiological-assessment-methodology

Initial Radiological Assessment Methodology: Part 1 user report
Initial Radiological Assessment Methodology: Part 2 Methods and data

c. Data values from EA models -IRAT 2 2020 / 2021

d. ICRP Publication 72. Age dependant Doses to Members of the Public from Intake of Radionuclides: Part 5, Annals of ICRP 26 (1), 1996.

e. ICRP Publication 68. Dose Coefficients for Intakes of Radionuclides by Workers: Annals of ICRP 24 (4), 1994

f. Radiological Assessments for Small Users, C E McDonnell, NRPB-W63, 2004

Figure 1 University of Essex Control of Material

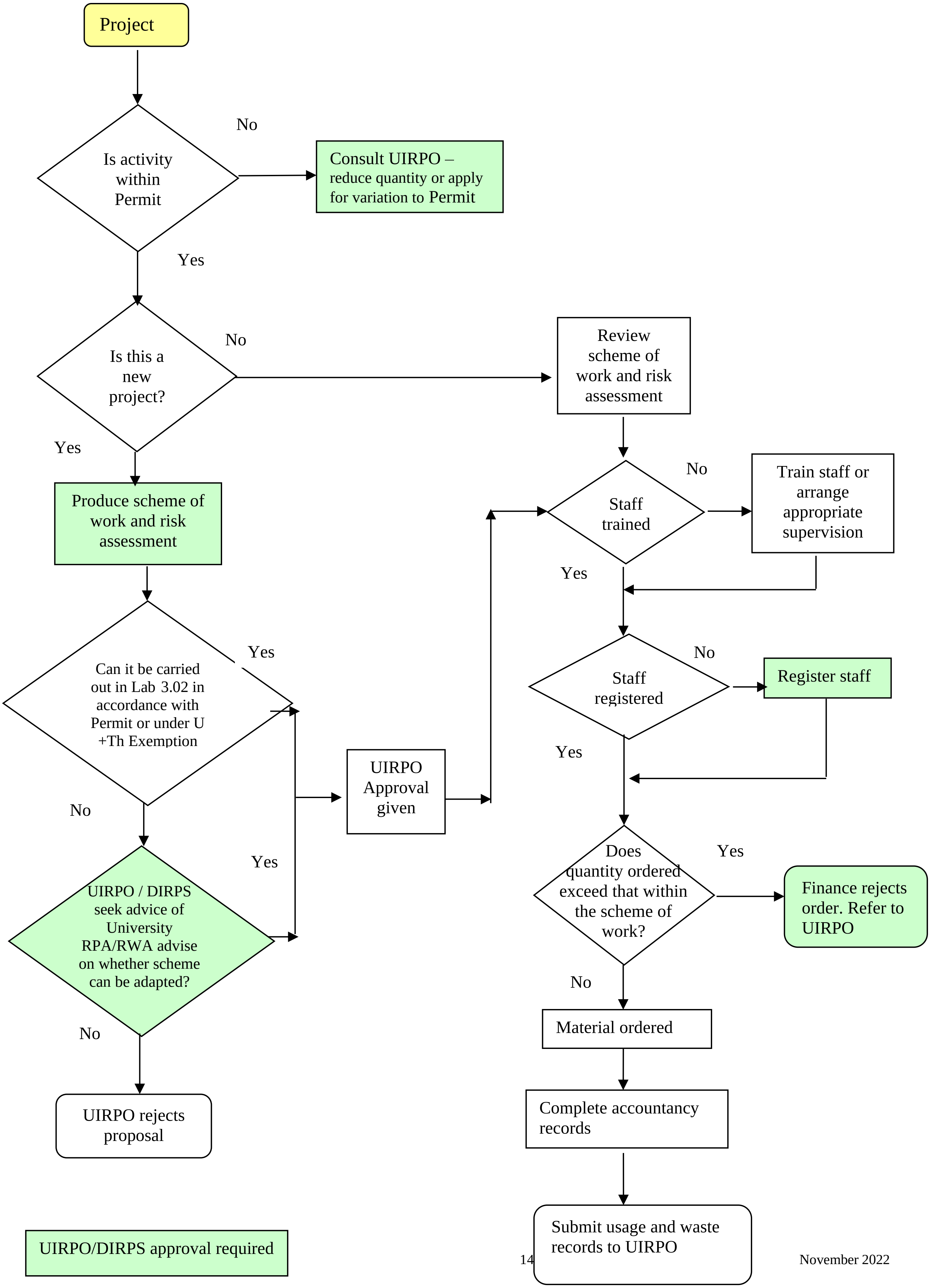
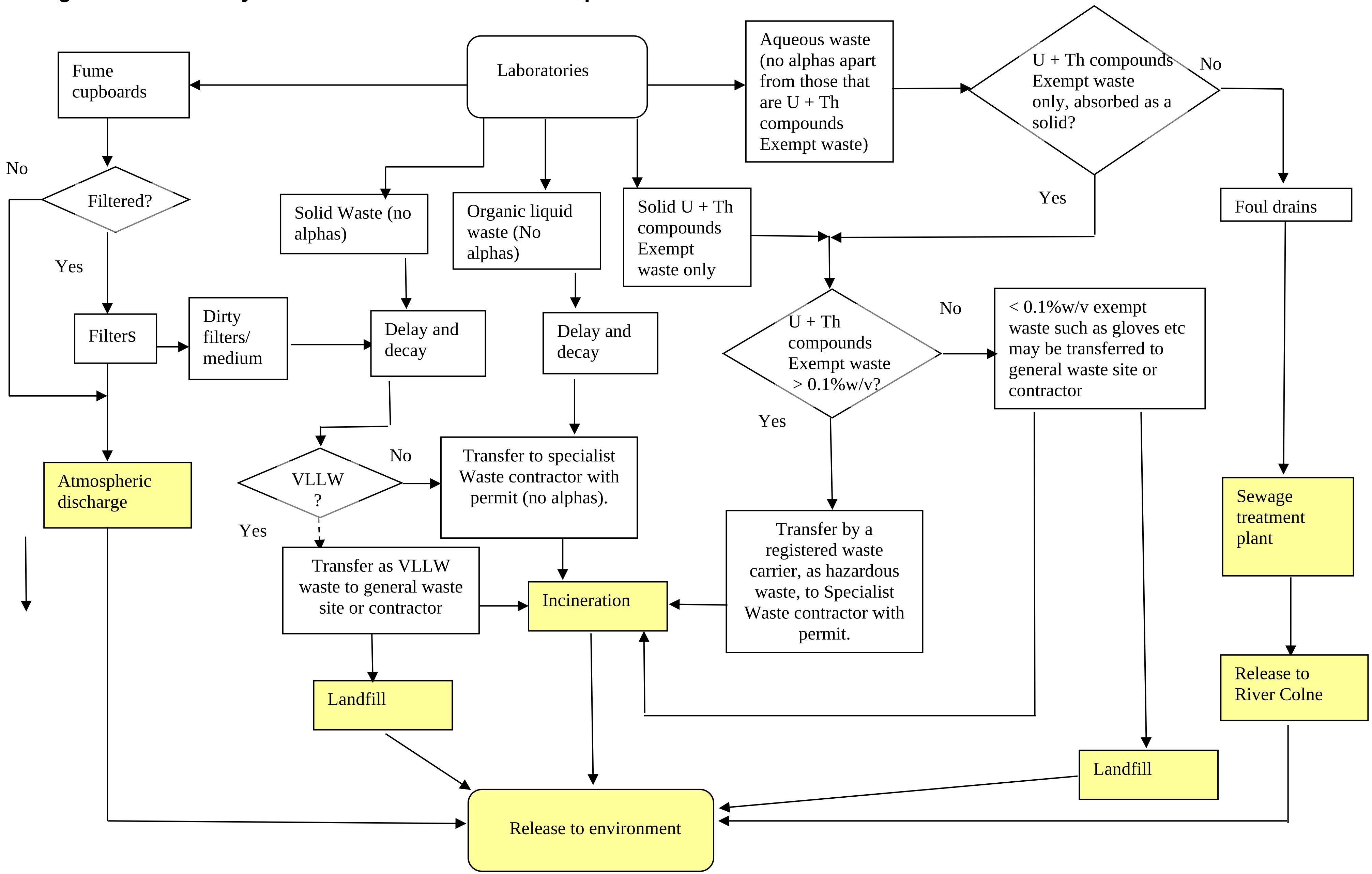


Figure 2 University of Essex Accumulation and Disposal of Radioactive Waste



Possible Public Exposure

- - -> **This route is not used at present -needs permission of the UIRPO**

ANNEXE A

RADIOLOGICAL DOSE ASSESSMENT AND REVIEW OF THE ACCUMULATION AND DISPOSAL OF RADIOACTIVE WASTE FROM THE UNIVERSITY OF ESSEX

1. Introduction and scope

This report has been produced as a result of a review of radioactive waste disposal from the University of Essex.

The assessment examines the various routes for disposal and the likely discharges resulting from the operations within Life Sciences.

2. Best Available Techniques Assessment

An assessment of the University's arrangements has been produced detailing the necessary managerial controls to demonstrate the use of best available techniques for the minimisation of use and disposal of radionuclides to the environment.

3. Conservation Areas

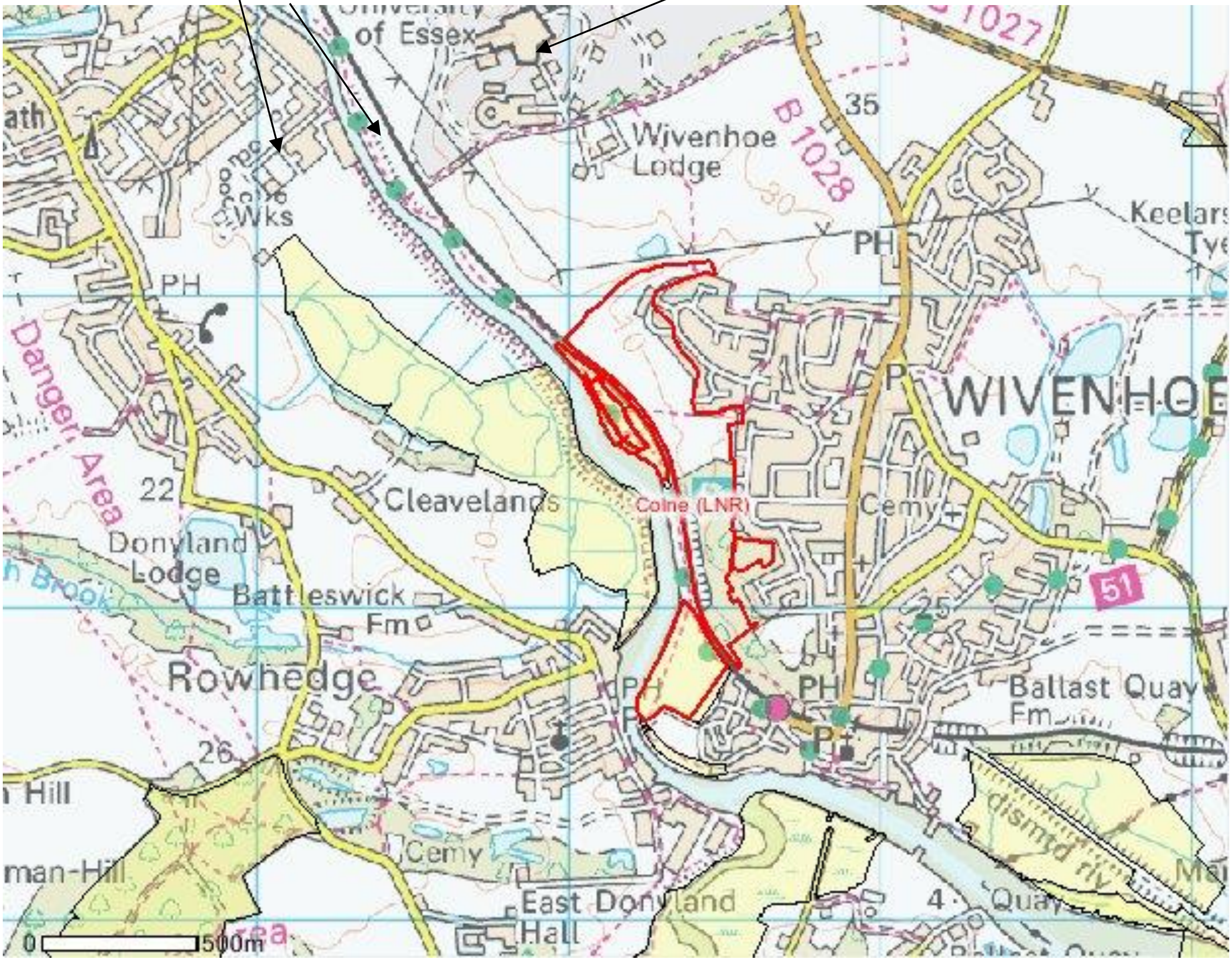
A survey of the local areas such as Conservation Areas and Sites of Special Scientific Interest has been carried out in support of the Habitat Directive.

The Upper Colne Marshes, Essex are registered as a Site of Special Scientific Interest (English Nature File Ref: 14 WA4). They lie along both sides of the River Colne and Roman River southeast of Colchester. The National Grid Reference is TM 022 232 – TM 050 209, area 114.1 hectare. The site consists of grazing marshes with associated ditch and open water habitats, a series of tidal salt marshes, sea walls and a small area of inter-tidal mud. It is considered to be of special interest because it supports an outstanding assemblage of nationally scarce plants and an unusual diversity of brackish ditch types. Additional interest is provided by the terrestrial and aquatic invertebrates found within the site, and breeding and wintering birds.

The site is located some 0.5 kilometres downstream from the sewage treatment works discharge point.

The river at the point the sewage treatment plant discharges is tidal.

Map courtesy of http://www.natureonthemap.naturalengland.org.uk/map.aspx?m=nreserves



Green areas show areas of Special Scientific Interest
Red shows local nature reserve

The River Colne is tidal.

4. Alternative Disposal Routes

Alternative disposal routes have been considered but have not been pursued because the quantities discharged are relatively low and the cost would be disproportionate to the benefits likely to be derived.

5. Radiological Assessment

5.1 Dose Assessment for disposal of waste

The majority of radioactive waste is either stored or transferred to a contractor for incineration or it is discharged as aqueous waste from the site. There is a very small quantity released to the environment as a gaseous discharge.

All aqueous discharges are via mains drainage with initial treatment at the sewage treatment plant in Haven Road, Colchester, operated by Anglian Water. Discharge is to the River Colne which is tidal at the discharge point. (Ref: TM 020 234)

5.2 Method

This dose assessment uses the excel model as provided by the Environment Agency IRAT (04/05/2022).

The model has a maximum river flow of $100ms^{-1}$ and this has been inputted. The Colne at the point of discharge from the sewage treatment plant is tidal and fishing is limited. critical group has been calculated to be members of the public who live in the vicinity of the site and consume locally caught fish. The STW has a biofuel unit which processes the sewage sludge. It is assumed that sewage sludge is both incinerated and discharged on agricultural land. There is no discharge to the river via a brook.

The pessimistic assumption has been made that the University uses the maximum activities allowed in the Environmental Permit.

A very pessimistic estimate of the release in a catastrophic fire has been made by assuming release at ground level and that the activity of all stocks of open sources and waste from open sources and all sealed sources has been released to air. Please see Appendix D for totals of activities from holdings including unsealed material, sealed sources and open source waste that would be released in an all-consuming fire.

One source term Barium -140 has been substituted for Barium-133 which has a similar ALI for inhalation and a much lower skin dose for the same activity.

5.3 Source Terms

Recently only carbon-14 was being used, however the permit allows for greater flexibility with its range of radionuclides. To ensure that the BAT assessment reflects potential future usage, a representative sample of radionuclides that could be used has been included in the calculations.

Radioactive Material – Open Sources

	Material on site (Becquerel)
Tritium	1×10^9
Carbon-14	1×10^9
Phosphorus-32	2×10^8
Any other nuclide except alpha emitters	2×10^8

Accumulation and Disposal of Radioactive Waste

All discharges are from the Life Sciences Building

Gaseous Discharge via fume cupboards

Carbon-14 2.5 x 10^8 Becquerels per year

Aqueous Disposals to sewer

	Monthly Discharge (Becquerel)	
Tritium	2 x 10^8	
Carbon-14	2 x 10^8	
Phosphorus-32	2 x 10^8	
Any others assumed to be:		
Sulphur-35	6.67 x 10^7	
Iodine-125	6.67 x 10^7	2 x 10^8
Iodine-131	6.67 x 10^7	

Disposal of aqueous waste is via authorised sinks only.

Organic liquid waste - Accumulation (365 days)

Any nuclide except alphas

Carbon-14 Phosphorus-32 Sulphur-35 Iodine-125 Iodine-131	30 x 10^6 Becquerel

Solid Waste - Accumulation (365days)

Any nuclide except alphas

Carbon-14 Phosphorus-32 Sulphur-35 Iodine-125 Iodine-131	300 x 10^6 Becquerel

Annual Waste Disposal via a Contractor

Any nuclide except alphas

Organic liquids 100 x 10^6 Becquerel

Solid waste 300 x 10^6 Becquerel

5.4 Transfer to the Environment

The principal routes for transfer to the environment are assessed as:

i) discharge of aqueous radioactive wastes to the environment
ii) gaseous discharge via the fume cupboard
iii) very low level waste
iv) accidental fire in facilities

5.5 Exposure Pathways

The main exposure pathways are considered to be:

i) Fishing family (estuary/ coastal) -food dose
ii) Angling dose (river Colne) -food dose
iii) Farming family (sewage sludge to land) (food dose)
iv) STW worker dose at STW
v) Irrigated food consumer (river)
vi) air -population groups -local resident (primarily food dose)
vii) air -wildlife group-terrestrial wildlife-worst affected
viii) exposure of the public to an atmospheric release as the result of an accidental fire.

5.6 Assessment of doses from discharges to the environment

Note the EA model limits the river flow to $100m^3s^{-1}$

Population Group	**Total Dose μSv.y^{-1}**	**Food Dose μSv.y^{-1}**
Fishing family (estuary/ coastal)	1.8	1.8
Angular dose (river)	1.2	1.2
Farming family (sewage sludge to land)	$5.8x\ 10^{-2}$	$5.8x\ 10^{-2}$
STW worker dose at STW	3.2×10^{-2}	
Irrigated food consumer (river)	1.5×10^{-3}	4.5×10^{-4}
Air – Local resident	7.1×10^{-3}	6.2×10^{-3}
Maximum -Human	**1.8**	**1.8**
Exposed Group	**Total Dose μSv.y^{-1}**	
Release by catastrophic fire (dose to resident)	**1.31**	**1.00**
Exposed Group	**Total Dose μGy.h^{-1}**	
Terrestrial Wildlife (sewage sludge to land) worst affected	4.2×10^{-3}	
River Wildlife worst affected	3.6×10^{-3}	
Coastal Wildlife worst affected	1.1×10^{-3}	
Air – Wildlife group-terrestrial wildlife -worst affected	2.1×10^{-5}	
Release by catastrophic fire (dose to wildlife group - terrestrial worst affected	8.9×10^{-4}	

Note no FSA consultation required.

5.7 Exposure as a result of fire

Using the IRAT air model (04.05.2022) to predict doses to a resident and wildlife, if all waste and material was consumed by a catastrophic fire. The effective release height was set at zero.

Based on the above, the committed effective dose equivalent to the public due to inhalation and external exposure in the event of a major fire is 1.31 μSv and to wildlife (terrestrial wildlife worst affected) is 8.9×10^{-4}. However, this is a pessimistic assumption because it is unlikely that the total holdings would be released in a fire.

This figure is not dissimilar to the results of the last but one BAT assessment using PC Cream.

6. Discussion of Results

The River Colne is a tidal river where the sewage treatment plant discharges. For the purpose of these calculations, it has been treated as a river. An analysis of the marine compartment was carried out using the EA Spread sheets, but doses were well below those used for inland rivers. It has been assumed for the purpose of this radiological assessment that the discharges are to a river rather than an estuary, erring on the side of caution.

The maximum dose to humans from all intended releases is 1.8 $\mu Sv.y^{-1}$ from a fishing family (estuary/ coastal) from the consumption of locally caught fish (100%).

The next highest was for anglers (river). The dose is 1.2 $\mu Sv.y^{-1}$ for anglers (river) from the consumption of locally caught fish (100%). As it is a tidal river this is over pessimistic, the water will be a mixture of salt water and sea water. Fishing takes place further up the river and is not likely to be significantly affected by the aqueous discharges due to dilution.

The farming family (sewage sludge to land) was 0.058 $\mu Sv.y^{-1}$

Following this is a dose of 0.0071 $\mu Sv.y^{-1}$ from the air, for local residents. The food dose is 0.0062 $\mu Sv.y^{-1}$.

The calculated doses to sewer workers are low this is 0.0032 $\mu Sv.y^{-1}$ probably due to the increased automation.

Also low was the irrigated food consumer (river) this is 0.0015 $\mu Sv.y^{-1}$
with only 30% attributed to the consumption of the irrigated food.

The calculations are based on the maximum annual discharges. These are very pessimistic and realistically doses will be well below the levels calculated. The University is surrounded by farmland. It is feasible that animals could graze on contaminated land and give rise to contaminated milk. However, it likely that milk products are sent to a central processing facility that dilutes it with other uncontaminated products.

The maximum inhalation dose due to a catastrophic fire to local inhabitants (intended releases) was 1.3 $\mu Sv.y^{-1}$ with the food dose caused by the fire 1.0 $\mu Sv.y^{-1}$

This is very pessimistic as it is unlikely all the activity would be released due to distribution of stores, fire resistance of sealed sources, apparatus and stores.

For wildlife, the dose rates for release by sewer are;

Terrestrial wildlife; 0.0042 $\mu Gy.h^{-1}$
River wildlife; 0.0036 $\mu Gy.h^{-1}$
Coastal; 0.0011 $\mu Gy.h^{-1}$

For wildlife, the dose rates for release by air (normal release) with the worst affected being for terrestrial wildlife; 0.000021 $\mu Gy.h^{-1}$

For wildlife, the dose rates for release by air (after a catastrophic fire) with the worst affected being for terrestrial wildlife; is 0.00089 $\mu Gy.h^{-1}$

7. Conclusion

The doses are well below the Euratom dose constraint of 0.3 mSv per site. The majority of the doses are well below the EA set 20 μSv dose for the representative group.

ANNEX B REPPIR ASSESSMENT

Use of pessimistic assessment using the maximum sources activities of open and sealed sources. It is unlikely that 100% of all radioactive substances will be subject to the fire.
The most pessimistic source term representing each group of radioactive substances was chosen. Sealed sources are kept in fireproof stores or in equipment which affords fire resistance.

Sealed sources: activity	Sources on site (activity in Bq).
Source terms used	Ni-63 7.4E+08 Ba-133 6.97E+05 Eu-152 4E+6
REPPIR ratio Sealed sources	$4.4X10^{-5}$

Open sources plus aqueous waste plus organic waste plus solid waste plus gaseous waste (C-14)	H-3 (OBT) 1.34E+09 C-14 1.59E+09 P-32 4.28E+08 S-35 (organic) 1.43E+08 I-125 9.31E+07 I-131 1.43E+08
REPPIR ratio open	0.00078
REPPIR ratio total	8.2X10-4

Schedule 1
The radionuclides and quantities in Schedule 1 have been derived by Public Health England (PHE, now UKHSA) modelling the consequences of a worst-case release (100% inventory ground level release of the radioactive material and waste present on site, modelling doses to members of the public at a distance of 100 m, and doses caused by contamination to food produced up to a distance of 1 km with a conservative 12-month occupancy of the emergency scenario.)

REPPIR would apply when an annual effective dose is greater than 1 mSv to a member of the public following a radiation emergency.

Sum of the ratios = 0.00082. Therefore, REPPIR does not apply.

The annual effective dose to a member of the public following a radiation emergency would be 0.78μSv by this model.

Appendix A

Normal release to sewage works

Name of premises	University of Essex				
Reference	IRAT Assessement 2022				
Where does effluent discharge from STW go?:					
To a brook?	No				
To a river direct from STW or via a brook?	Yes				
To estuary/coast direct from STW or via a brook or river?	Yes				
Where does the sewage sludge from STW go?:					
To agricultural land?	Yes				
To an incinerator?	Yes				
Data entry:					
Sewage works	Haven STW				
Average raw sewage flow rate	27000	m^3/day		User defined value	
Average brook flow rate	0.1	m^3/s			
Average river flow rate	100	m^3/s			
Coastal Location	Default value				
Average coastal/estuary exchange rate	30	m^3/s		User defined value	

Population group	**Total dose**		**Food Dose**	
STW worker dose at STW	3.2E-03	µSv/y		
Child playing in brook	0.0E+00	µSv/y		
Angler dose (river)	1.2E+00	µSv/y	1.2E+00	µSv/y
Irrigated food consumer (river)	1.5E-03	µSv/y	4.5E-04	µSv/y
Fishing family (estuary/coastal)	1.8E+00	µSv/y	1.8E+00	µSv/y
Farming family (sewage sludge to land)	5.8E-02	µSv/y	5.8E-02	µSv/y
Maximum	1.8E+00	µSv/y	1.8E+00	µSv/y
FSA consultation required for non-nuclear permit?	**No**			

Wildlife Group	**Total dose rate**	
River wildlife - Worst affected	3.6E-03	µGy/h
Coastal wildlife - Worst affected	1.1E-03	µGy/h
Terrestrial wildlife (sludge to land) - Worst affected	4.2E-03	µGy/h

	Name	**Signature**	**Date**
Assessed by	Niall Higbee	NCH	02/11/2022
Reviewed by			

Guidance

1. The spreadsheet is colour coded as follows:

(blue)	Row and column headings
(yellow)	Data entry by user
(light cyan)	Data provided in spreadsheet
(orange)	Results and interim calculations

2. Assessment Details - Enter the relevant data on this sheet. You must answer the questions relating to the route of the treated effluent as this will ensure that doses are only calculated for the appropriate population groups. Depending on the discharge route you may enter the raw sewage flow rate, the average brook flow rate, river flow rate and estuary/coastal water exchange rate. Information that is not required is greyed out. Default values are provided if the information is not available.

3. Releases to sewer - Enter the limits for each radionuclide on this sheet. You may need to select surrogate radionuclides or use the other alpha and other beta gamma categories.

4. Summary total dose - The results are displayed on this page along with the percentage contribution from each radionuclide.

5. STW worker dose, sludge land farmer dose, Child in brook dose, River Angler dose, Irrig food dose and Coastal Fisherman dose - The dose contribution from each exposure pathway for these population groups are shown.

6. Sludge land wildlife dose, River wildlife dose, Coastal wildlife dose - The dose contirbution from each exposure pathway for the worst affected reference organisms is shown.

7. STW data, Coastal exchange rates, Partitionining & Decay factors - Shows the site or situation specific values which are used in the calculations when default values are refined.

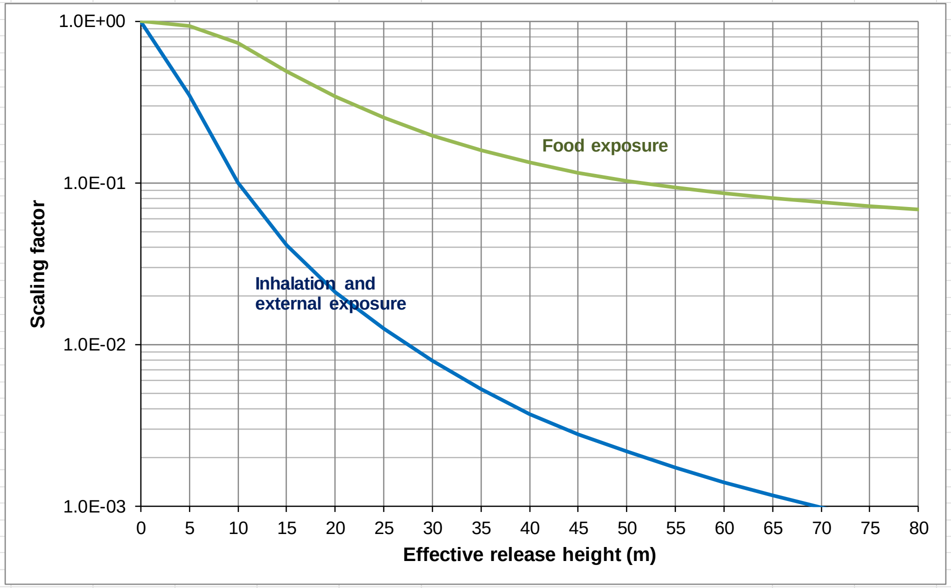
8. If sewage sludge from the STW to an incinerator is selected in the Assessment Details tab, this will calculate and populate an incinerator feedstock column in the Release to Sewer tab. The incinerator feedstock values can then be exported and used as the release to air discharge information in the IRAT2 - Release to Air tool in order to assess the impact of releases to atmosphere from incineration of sludge.

Appendix B

Normal release to air

Name of premises	University of Essex Normal				
Reference	BAT Assessment 2022				
Are the discharges from an incinerator?	No				
Incinerator type					
Include Partition Factors?					
Effective release height (m)		10			
Inhalation & external exposure scaling factor		0.100357	User defined value		
Food exposure scaling factor		0.733333	User defined value		
Population groups		**Total dose**		**Food dose**	
Local resident		7.1E-03	**µSv/y**	6.2E-03	**µSv/y**
FSA consultation required for non-nuclear permit?		**No**			
Wildlife Group		**Total dose rate**			
Terrestrial wildlife - Worst affected		2.1E-05	**µGy/h**		

	Name	**Signature**	**Date**
Assessed by	Niall Higbee	NCH	02.11.2022
Reviewed by			



Guidance

1. The spreadsheet is colour coded as follows:

(blue)	Row and column headings
(yellow)	Data entry by user
(light blue)	Data provided in spreadsheet
(orange)	Results and interim calculations

2. Assessment Details - Enter the relevant data on this sheet. Enter dispersion scaling factors to take account of release height or select the nearest height from the drop down list. Separate scaling factors should be entered for the inhalation & external exposure and the food exposure. Scaling factors for different release heights are shown in the figure or in the 'Atmospheric Dispersion' tab. Where no release height data is available a scaling factor of 1 should be used.

3. Release to Air - Enter the limits for each radionuclide. You may need to select surrogate radionuclides or use the other alpha and other beta gamma categories.

4. The results by each radionuclide are displayed on the sheet 'Summary total dose'.

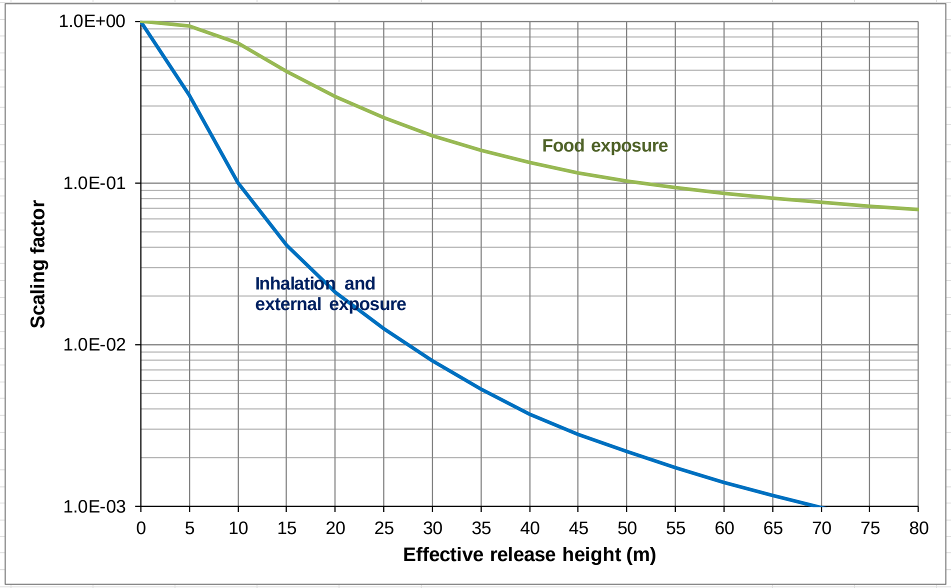
5. The dose contribution from each exposure pathway for this population group are shown in sheet 'Local resident dose'.

6. Dose rates to wildlife from each radionuclide are shown in 'Terrestrial wildlife dose'

Appendix C

Release to air by catastrophic fire

Name of premises	University of Essex Catostrapic fire				
Reference	BAT Assessment 2022				
Are the discharges from an incinerator?	No				
Incinerator type					
Include Partition Factors?					
Effective release height (m)		0			
Inhalation & external exposure scaling factor		1	User defined value		
Food exposure scaling factor		1	User defined value		
Population groups		**Total dose**		**Food dose**	
Local resident		1.3E+00	**µSv/y**	1.0E+00	**µSv/y**
FSA consultation required for non-nuclear permit?		**No**			
Wildlife Group		**Total dose rate**			
Terrestrial wildlife - Worst affected		8.9E-04	**µGy/h**		
	Name		**Signature**		**Date**
Assessed by	Niall Higbee		NCH		02.11.2022
Reviewed by					



Guidance

1. The spreadsheet is colour coded as follows:

(blue)	Row and column headings
(yellow)	Data entry by user
(light cyan)	Data provided in spreadsheet
(orange)	Results and interim calculations

2. Assessment Details - Enter the relevant data on this sheet. Enter dispersion scaling factors to take account of release height or select the nearest height from the drop down list. Separate scaling factors should be entered for the inhalation & external exposure and the food exposure. Scaling factors for different release heights are shown in the figure or in the 'Atmospheric Dispersion' tab. Where no release height data is available a scaling factor of 1 should be used.

3. Release to Air - Enter the limits for each radionuclide. You may need to select surrogate radionuclides or use the other alpha and other beta gamma categories.

4. The results by each radionuclide are displayed on the sheet 'Summary total dose'.

5. The dose contribution from each exposure pathway for this population group are shown in sheet 'Local resident dose'.

6. Dose rates to wildlife from each radionuclide are shown in 'Terrestrial wildlife dose'

Appendix D

Summary sheet for radioactive substances, gaseous, aqueous and solid discharges

Source Term	Unsealed source holdings (Bq)	Sealed Source holdings (Bq)	Solid waste (Bq)	Organic waste (Bq)	Gaseous waste (Bq/y)	Aqueous Discharge (Bq/y)	Total Source Holdings (Bq)
Tritium (OBT)	1.00E+09		1.26E+08	1.26E+07		2.00E+08	1.34+09
Carbon-14	1.00E+09		1.26E+08	1.26E+07	2.50E+08	2.00E+08	1.59+09
Phosphorus-32	2.00E+08		2.50E+07	2.50E+06		2.00E+08	4.28+08
Sulphur-35 (organic)	6.67E+07		9.00E+06	9.00E+05		6.67E+07	1.43+08
Iodine-125	6.67E+07		9.00E+06	9.00E+05		6.67E+07	9.31+07
Iodine-131	6.67E+07		9.00E+06	9.00E+05		6.67E+07	1.43+08
Nickel-63		7.40E+08					7.40E+08
Barium-133		6.97E+05					6.97E+05
Europium -152		4.00E+06					4.00E+06