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Environmental
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Project

Assessment of the Radiological Health Risk associated with ANSTO Effluent Release:

including the Reuse of Tertiary Treated Sewer Water and Sludge and the Impact of Effluent Entering Local Waterways with Sewer Surcharge.

prepared by

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EXECUTIVE SUMMARY

An analysis has been made of the radiological consequences of the release of ANSTO's aqueous discharge to the Cronulla sewage system. This is in response to Condition 10 of the Environmental Impact Statement supporting the Replacement Research Reactor. The analysis covers the release of effluent under normal conditions, the release of effluent as part of a sewage surge during periods of high rainfall, and the impact of the decision by Sydney Water to recycle treated sewage sludge and sewage water.

Normal operations: Operations associated with normal effluent release have negligible radiological health effect on the community. An analysis of critical groups has been undertaken. The highest dose was that received through the ingestion of fish caught in the general vicinity of Potter Point. The dose is predominantly from the alpha emitters and amounts to 0.16 microSv. In this calculation it was assumed that all activity released to the sewage system for the calendar year 2001 (not yet publicly available) passed through the Cronulla Sewage Treatment Plant (STP). All alpha emitters were assumed to be Ra-226 and all beta emitters were assumed to be Sr-90.

Radiological impact of a sewage surge: In response to questions raised over the possible impact of releases during sewage surges, ANSTO established a tritium monitoring location at Forbes Creek. The catchment of this creek would receive water from one of the sewage surge points. Tritium is the nuclide at highest concentration; however no statistically significant levels have been observed.

Another approach to this assessment involves consideration of dilution factors between Lucas Heights and the surge points. During the year 2000 (ANSTO/E/745), the average levels of alpha emitters, beta emitters and tritium were <0.9 Bq/L. 13.5 Bq/L and 21.8 kBq/L respectively, at the ANSTO site discharge point. These are all within a factor of three of the WHO Drinking Water Reference Levels. Under dry weather conditions, the levels at the STP would be diluted to <0.8%, <1.2% and 1.2% of the WHO values respectively. Surge events would occur during periods of high rainfall when the dilution factors would be higher than average and any surge water would be further substantially diluted by catchment run-off. Radionuclide concentrations would be very much lower than the WHO drinking water values and would constitute no hazard to health.

Recycling of sewage water: Associated with the upgrade of the STP are plans to recycle sewage sludge as a slow release fertiliser and to reuse treated water for non-potable purposes. The calculations in this report are based on operating conditions based on the STP Environmental Impact Statement and on ANSTO releases to the sewer system in the calendar year 2000 (ANSTO/E/745). It is conservatively assumed that all the tritium is retained in the aqueous phase and all alpha and beta emitting isotopes are adsorbed on the sludge. The average level of tritium in the recycled water during average dry weather flow is 91 Bq/L or 1.2% of the WHO Drinking Water Reference standard.

Recycling of sewage sludge The specific levels of alpha and beta emitting isotopes in the sludge are 1.3 and 19 Bq/kg. These are less than 0.5 and less than 6 per cent respectively of

the background levels of soils representative of the Lucas Heights region. The total specific activity (20.3 Bq/kg) on the sludge may be compared with that of 5000 Bq/kg for superphosphate quoted in the document 'Radiation and Life' on the UIC website (www.uic.com.au/ral.htm). It should be noted that because of other considerations (such as heavy metal accumulation), the use of sludge is generally restricted to one application on each agricultural plot.

In the very unlikely event that a significant fraction of the radionuclides were dissolved in the aqueous phase and not adsorbed on the sludge, the maximum, specific activities for the alpha and beta emitting isotopes would be <0.004 and ~0.6 Bq/L. These values are equivalent to <0.8% and <1.2% of the WHO Drinking Water Levels respectively.

Critical Groups A critical group analysis is being undertaken separately (ANSTO/EMAP/TN-01). It suffices here to note that two critical groups have been identified:

- People consuming fish in the vicinity of Potter Point. Assuming 30 kg fish are consumed annually, the dose is will be 0.17 microSv. Details are presented in the reference.
- A front end loader driver transporting an average of 100 kg sludge for 100 hr/year (average operational time at the Cronulla STP). The accumulated annual dose is 0.12 microSv.

General conclusion: It may be confidently concluded that there are no radiological health effects associated with ANSTO operations, or with the recycling of the sewage water or the sludge. Indeed, it is expected that the release of low level aqueous effluent will continue to fall over future years as a consequence of 1) the implementation of new technology leading to significantly decreased releases; 2) environmental benefits derived from the implementation of the ISO 14000 Environmental Management System, and 3) reduced tritium release following commissioning of the Replacement Research Reactor.

Although this report specifically addresses issues arising out of Condition 10 of the Replacement Research Reactor EIS, it also covers the matter raised in Recommendation 4 of the ARPANSA Nuclear Safety Committee, namely:

- Prior to issuing a Construction Licence, ANSTO submit to the CEO of ARPANSA a health risk assessment for reuse of sewer water containing ANSTO radioactive wastes and an ecological risk assessment for ANSTO radioactive wastes entering local waterways with sewer surcharge.

Hence there is no need for further health assessments.

CONTENTS

1. INTRODUCTION

1.1 Background

The purpose of this report is to address aspects of condition 10 associated with the approval of the Research Reactor Review Environmental Impact Statement that relate to liquid effluent discharges, namely:

A high priority must be given to the review and licensing of radioactive waste discharges to sewer by ANSTO. As part of this, ANSTO should be required to undertake further assessment and analysis to ensure that all possible exposure pathways and future events at the Cronulla Sewage Treatment Plant are taken into account. Monitoring and assessment of individual discharges within the LHSTC is also desirable, to enable understanding of the various sources and their relative contributions. This assessment must be prepared to the satisfaction of ARPANSA and prior to reactor operations commencing.

ANSTO operations that involve radiation or radioactive material are regulated under the Australian Radiation Protection and Nuclear Safety Act 1998, the object of which is to protect the health and safety of people and to protect the environment from the harmful effects of radiation. The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) has been established to implement the provisions of the Act and the associated regulations. Under the Act ARPANSA has the authority to undertake independent audits of the effluent and environmental monitoring programs at ANSTO sites.

ANSTO has a Health, Safety and Environment Policy that commits the Organisation to undertaking its activities in a manner that protects human health and the environment, and is consistent with national and international standards. The Policy further mandates that all procedures are in accordance with Commonwealth legislation and take account of relevant NSW regulations and Australian and international standards on environmental management and quality systems. ANSTO is committed to providing verifiable evidence of the fulfilment of the policy through a program of monitoring and audit.

Broadly speaking, ARPANSA guidelines for the routine discharge of radioactive waste to the sewage system and to the atmosphere are based on the following documents:

- Commonwealth of Australia (1999), *Australian Radiation Protection and Nuclear Safety Regulations 1999*, Commonwealth Government Printer, Canberra; and
- National Health and Medical Research Council (1985), *Code of Practice for the Disposal of Radioactive Wastes by the User (1985)*, AGPS: Canberra.

In addition, ANSTO complies with the provisions of the Sydney Water Trade Wastewater Agreement (No. 4423, 1999). The low-level liquid effluent is chemically treated, analysed and documented to verify compliance with authorised limits before discharge to the Sydney Water sewer. Authorised discharge limits for radioactivity are based upon the WHO Guidelines for Drinking Water Quality, that is:

" ...average monthly activity concentrations of discharges by ANSTO to the Sydney Water Corporation sewer shall not exceed 25 times the reference activity concentrations for radionuclides

as determined by the application of the methodology specified in the WHO *Guidelines for Drinking-water Quality,* Volume 1 Recommendations, Second Edition (1993), corresponding to the reference level of dose of 0.1 mSv/year."

Sydney Water has recently upgraded the Cronulla Sewage Treatment Plant (STP) for the tertiary treatment of sewage. Plans involve the recycling of sewage sludge for application as a slow release fertiliser on agricultural plots and the treated water for non-potable purposes. The implementation of these plans gives rise to possible exposure pathways, which need to be assessed.

1.2 Low Level Effluent Release

ANSTO releases low level effluent to the sea off Potter Point through the Cronulla Sewage system under the above-mentioned Trade Waste Water Agreement with Sydney Water. ANSTO monitors compliance with the Agreement during each release. Further the Organisation undertakes bi-annual investigations of the transport of radionuclides through the STP and out to sea at the Potter Point outfall.

The investigations involve measurement of the transit times and dilution factors for radionuclides between Lucas Heights and the STP. Between 1995 and 2000, the transit times varied from 9.8 and 12 hours and the dilution factors between 22 and 50. An investigation has been made subsequent to the upgrade of the plant for tertiary treatment of the sewage. An enhanced dilution factor of about 250 was recently observed (December 2001) largely due to the enhanced residence times of sewage effluent within the upgraded plant.

The monitoring data are published annually as public documents within the series *Environmental and Effluent Monitoring Reports at ANSTO Sites.* These documents confirm that ANSTO has always operated in compliance with the Trade Waste Agreement and all other applicable regulations and guidelines.

1.3 Sewage Surcharge

Sydney Water has built into the sewage system a number of surge points to cope with very high flows, which can occur during abnormal conditions. The issue of whether significant levels of radionuclides from the Lucas Heights site are released to catchments during surge events was raised. In response to this issue, ANSTO established a tritium monitoring location at Forbes Creek. The catchment of this creek would receive water from one of the sewage surge points. Tritium is monitored because it is the nuclide at highest concentration. No statistically significant levels have been observed.

Further, calculations have been used to demonstrate that the radiological impact of ANSTO derived radionuclides that might be released with a sewage surge would be entirely negligible.

1.4 Recycling of Sewage Sludge and Water

Estimates of the levels of ANSTO radionuclides in sewage sludge and recycled water are based on specifications listed in the EIS for the Cronulla STP (Connell Wagner, 1997), namely:

- The release of up to 2 ML/d (megalitre per day) of tertiary treated water for reuse in urban areas;
- The screening of raw sewage and the removal of app 200kg/day (dry weight) to an approved landfill;
- The removal of grit and the transportation of app 400 kg/day (dry weight) of grit to an approved landfill;
- The tertiary treatment of sediment fines and the production of biosolids for beneficial use in agriculture and forestry.

Three possible pathways for the transport of ANSTO low level aqueous effluent to the environment via recycled sewage are considered. These are

Pathway 1 Alpha and beta emitting isotopes on the grit, screenings and biosolids

Pathway 2 Tritium in the recycled water*

Pathway 3 Alpha and beta isotopes in the recycled water

* An aerosol pathway has not been considered separately for tritium (water) as the radiological effects are the same as the ingestion pathway.

2. RISK ASSESSMENTS ASSOCIATED WITH EFFLUENT RELEASE

2.1 Low Level Effluent Release

In compliance with the Trade Waste Agreement, levels of radionuclides at the Cronulla STP comply with the WHO Drinking Water Reference standards assuming a dilution factor of 25 between ANSTO and the treatment plant. With the upgrade of the plant for the tertiary treatment of sewage, early measurements indicate that the dilution factor is about an order of magnitude greater than that nominated in the Agreement , say about 250. This implies that the levels of radioactivity at the STP would be a factor of 10-or-more less than the WHO Drinking Water reference values. Clearly they would not give rise to any radiological health effects to the workers or the community.

In 1999 ANSTO and ARPANSA thermoluminescent dosimeters were located in the Cronulla STP. Both recorded an effective dose of 0.6 mSv/year. This was the lowest of any of the four recording points in the Sutherland Shire and is entirely due to normal background radiation.

2.2 Sewage Surge

As indicated in the previous section, a tritium monitoring point was established at Forbes Creek, in an attempt to monitor possible impacts of ANSTO radionuclides entering the catchment through a sewage surge point during heavy rainfall periods. No statistically significant levels of tritium have been observed.

Another approach to this assessment involves consideration of dilution factors between Lucas Heights and the surge points. During the year 2000, the average levels of alpha emitters, beta emitters and tritium were <0.9 Bq/L. 13.5 Bq/L and 21.8 KBq/L respectively. These values are all within a factor of three of the WHO Drinking Water Reference Levels. Sewage flows from Engadine and Heathcote augment those from ANSTO before the Forbes Creek surge point. This would lead to substantial dilution of the radionuclides from the effluent release. By the time the flow has reached the STP, the levels of alpha emitters, beta emitters and tritium have been diluted to <0.8%, <1.2% and 1.2% of the WHO values respectively under dry weather conditions (Table 1). Surge events would occur during periods of high rainfall when the dilution factors would be higher than average. In addition, any surge water would be further substantially diluted by catchment run-off. Radionuclide concentrations would be very much lower than the WHO drinking water values and would constitute no hazard to health.

As stated before, monitoring has shown no statistically significant levels in surge affected creeks.

2.3 Reuse of Sewage Water

Calculations of the levels of ANSTO radionuclides in recycled water and sewage sludge involve the following assumptions:

1) It is assumed that all the alpha and beta activity is adsorbed on the solids except for the assessment of pathway 3. The solids are classified as:

   - those separated and transported to the landfill (the grit and screenings), and

   - those sediment fines which are available for disinfection and conversion to biosolids for agricultural use.

2) It is assumed that all the tritium, which is released from ANSTO as tritiated water is retained in the aqueous phase. There is no mechanism for the concentration of tritium after it is released to the sewer, and effectively no mechanism whereby it can be associated with the dry solids.

3) The calculation will be based on the data published in the EIS supporting the Cronulla STP upgrade, namely:

- Weight of grit and screenings 2.19×10^5 kg/year (1)

  (600 kg/d, Connell Wagner, 1997)

- Estimated weight of fines (refer Pathway 1 below) 56×10^6 kg/year (2)

- Total solids ((1) + (2)) 56.2×10^6 kg/year (3)

- Average dry weather flow (53 ML/d, Connell Wagner, 1997) 19.3×10^9 L/y (4)

4) The level of the radioactivity is expressed as a specific activity ie as (Bq/kg) for solids and (Bq/L) for liquids. For comparison, the radioactivity on the solids are compared to the average measured alpha or beta activities on soils at Lucas Heights. The level of radioactivity in the liquids are compared with the WHO Drinking Water Reference Concentrations

5) The levels of radioactivity released to the sewer were those for the year 2000 as reported in Table 21 of the Environmental and Effluent Monitoring Report(Hoffmann, et al, 2001). The assumed sewage flow was the average dry weather flow (53 ML/d) reported in the Cronulla Sewage Treatment Plant Upgrade EIS.

2.3.1 Pathway 1: **Alpha and beta emitting isotopes in sewage grit and screenings**

As indicated above, the annual flow is assumed to be 19 x 10^9 litre, and the weight of grit and screenings is 2.19 x 10^5 kg/year.

To calculate the amount of sediment fines, it is noted (Connell Wagner, 1997) that there are six rectangular retention tanks (60m long, 10m wide and 5.5m deep). Assuming an average depth of 5 m and the quoted solids concentration of 2500 mg/L (ie 2.5 kg/m^3), the mass of solids in each tank would be 6 (tanks) x 60 (m) x 10 (m) x 5 (m) 2.5 (kg/m^3) ie 45,000 kg. The quoted hydraulic detention time is 7 h at average dry water flow rates. Hence the annual throughput of sediment fines is 45,000 (kg) x 365 (d) x 24 (h/d)/7 (h) ie 56 x 10^6 kg/year.

The total weight of solids is therefore 56 x 10^6 + 2.19 x 10^5 kg/year ie 56.2 x 10^6 kg/year.

In the year 2000, the total alpha and beta activity released was less than 72 MBq and 1090 MBq (or 10.9 x 10^8 Bq) respectively (Hoffmann, et al, 2001).

Hence the specific activity of the alpha emitters is <72 x 10^6 Bq/56.2 x 10^6 kg ie **<1.3 Bq/kg**. This is less than 0.5 per cent of the average value of the alpha activity of soils measured at Lucas Heights (338 Bq/kg).The average values are listed in the summary table.

The corresponding specific activity beta emitting radionuclides on the grit and screenings is 10.9 x 10^8 Bq/56.2 x 10^6 kg ie **19 Bq/kg**. This is less than 6 per cent of the beta activity on soils at Lucas Heights (351 Bq/kg, as listed in the summary table).

The screenings and grit will be removed to designated landfills. The sediment fines will, at least be converted to biosolids for beneficial use in agriculture or forestry. The biosolids will effectively be acting as slow release fertilizers.

Two comments can be made:

1. ANSTO is continuously improving its waste treatment technology and is moving towards very low release for alpha and beta emitters. Even under the current situation, the level of radioactivity derived from ANSTO is much less than the natural variability within the soils.

2. The total specific activity (19 + 1.3 = 20.3 Bq/kg, see above) on the sludge may be compared with that of 5000 Bq/kg for superphosphate quoted in the document 'Radiation and Life' on the UIC website (www.uic.com.au/ral.htm). It should be noted that because of other considerations such as the potential for heavy metal accumulation, the use of sludge is restricted to one application on each agricultural plot.

Since the specific activity of ANSTO derived radionuclides on sewage sludge is only a few percent of that on local soils (say <7%) or on superphosphate (say <1%), it may be confidently asserted that ANSTO's operations will not lead to any adverse radiological health effects as a consequence of recycling sewage sludge.

2.3.2 PATHWAY 2: **Tritium in the recycled water.**

The total tritium released from ANSTO in 2000 was 1760 GBq ie 1760 x 10^9 Bq. Assuming an average dry weather flow of 53 ML/d, the volume of effluent was 19 x 10^9 L/y. Hence the average tritium concentration would be 1760 x 10^9 (Bq/y)/19.3 x 10^9 L/y) ie 91 Bq/L. The WHO reference level for tritium in drinking water is 7800 Bq/L.

Hence, the average tritium level in the recycled water is 91/7800 ie 1.2 per cent of the WHO Drinking Water reference level and hence does not constitute a radiological health hazard. It will be noted that there is no mechanism for the concentration of tritium after release from ANSTO, and further, the recycled water will not be used for drinking purposes.

2.3.3 PATHWAY 3: **Alpha and beta emitting isotopes in the recycled water.**

This is the least likely of the three pathways as it implies that the alpha and beta emitting radionuclides are not adsorbed on the solid phase contrary to frequent observations. Never the less, it is included for completion. The calculations are similar to those for tritium (Pathway 2). In the year 2000, the total alpha and beta activities released to the sewerage system were <72 MBq and 1090 MBq respectively and the volume of water released was 19x 10^9 L. Hence, the specific activities of the alpha and beta emitters are respectively, <0.004 and 0.06 Bq/L respectively.

In assessing the impact, that all the alpha isotopes are evaluated as ^{226}Ra (as stipulated in the ANSTO Sydney Trade Waste Agreement) all the beta isotopes are evaluated as ^{90}Sr. The WHO drinking water reference concentrations for these isotopes are 0.49 Bq/L and 4.9 Bq/L respectively. The concentrations of alpha and beta radionuclides calculated above are <0.004/0.49 ie 0.8 per cent and 1.2 per cent of the WHO drinking water reference levels respectively.

The recycling of part of the water will not lead to adverse health effects, especially as the water will not be used for drinking. The calculations produce a large over estimate as no account has been taken of the uptake of the isotopes by the solids in the effluent which are separated from the recycled water. It will be recalled that in assessing the upper limit of the impact ANSTO's operations on the biosolids and the grit/screening material, it was assumed that ALL the alpha and beta emitters were adsorbed on the solid phases and hence none would be found in the recycled water.

2.4 Results

The results of the calculations are summarised in Table 1.

TABLE 1: **Summary of data**

Parameter	**Radionuclide pathway**			**Comment**
	Pathway 1 (sediment sludge – biosolids))	Pathway 2 (recycled water – tritium)	Pathway 3 (recycled water alpha and beta)	
Total flow (L)		19.3 x 10^9	19.3 x 10^9	
Total alpha (MBq)	<72		<72	
Total beta (MBq)	1090		1090	
Total tritium (GBq)		1761		
Mass screenings + grit (kg/year)	2.19 x 10^5			
Mass sediment fines (kg/year)	56 x 10^6			
Specific activity (Bq/kg)	1.3 (alpha) 19 (beta)			Average level of radioactivity on Lucas Heights soils: Alpha: 338 Bq/kg Beta: 351 Bq/kg
Activity expressed as a percent of levels on Lucas heights soils	<0.5 % (alpha <6 % (beta)			
Specific activity (Bq/L)		91 Bq/L	Alpha <0.004 Beta ~0.06 Bq/L	WHO Drinking Water Reference Levels: Tritium; 7800 Bq/L Ra-226 (a) 0.49 Bq/L Sr-90 (b) 4.9 Bq/L
Activity expressed as a percent of WHO Drinking Water reference Levels*		1.2% (tritium) (12 nanoSv/a)	Alpha <0.8% (<8 nanoSv/a) Beta <1.2% (<12 nanoSv/a)	

*The annual dose values in parenthesis have been calculated on the basis that 100 mL of the sewage sludge have been ingested throughout the year.

3. CONCLUSIONS

Operations associated with normal effluent release or with sewage surcharge during periods of heavy rainfall have negligible radiological health effect on the community. An analysis of critical groups has been undertaken. The highest dose was that received through the ingestion of fish caught in the general vicinity of Potter Point. The dose is predominantly from the alpha emitters and amounts to 0.16 microSv. In this calculation it was assumed that all activity released to the sewage system for the calendar year 2001 passed through the Cronulla STP. All alpha emitters were assumed to be Ra-226 and all beta emitters were assumed to be Sr-90.

3.1 Reuse of Treated Sewage Water

The clear conclusion is that additional radionuclide pathways associated with the reuse of tertiary water and of disinfected biosolids will have no adverse radiological effect on the community.

As indicated above, the levels of alpha and beta isotopes released to the sewage system will be reduced as ANSTO moves towards the installation of new technology, which will significantly reduce releases. The level of tritium released will be reduced with the construction of the Replacement Research Reactor.

3.2 Sewer Surcharge

The general conclusion is that ANSTO's operations will not result in any adverse radiological consequence derived from the decision to recycle treated sewage water or from release of surge water. Much of the argument is based on the fact that the levels of radionuclides in the sewage surcharge, derived from ANSTO, are small percentage of the WHO Drinking Water Reference Levels.

The WHO reference levels are determined on the basis that if the water were used as the sole source of drinking water, the dose to the individual would not exceed the limit defined for a member of the public.

No radiological health impacts will result.

3.3 Critical Groups

A critical group analysis is being undertaken separately (ANSTO/EMAP/TN-01). It suffices here to note that two critical groups have been identified:

1. People consuming fish in the vicinity of Potter Point. Assuming 30 kg fish are consumed annually, the dose is will be 0.17 microSv. Details are presented in the reference.

2. A front end loader driver transporting an average of 100 kg sludge for 100 hr/year (average operational time at the Cronulla STP). The accumulated dose is 0.12 microSv.

3.4 Concluding Comment

Although this report specifically addresses issues arising out of Condition 10 of the Replacement Research Reactor EIS, it also addresses the matter raised in Recommendation 4 of the ARPANSA Nuclear Safety Committee, namely:

- Prior to issuing a Construction Licence, ANSTO submit to the CEO of ARPANSA a health risk assessment for reuse of sewer water containing ANSTO radioactive wastes and an ecological risk assessment for ANSTO radioactive wastes entering local waterways with sewer surcharge.

4. REFERENCES

Connell Wagner P/L , (1997). *Cronulla Sewage Treatment Plant Upgrade: Environmental Impact Statement* Addendum)

Hoffmann, E.L., Loosz, T., Mohkber-Shahin, L., (2001). *Environmental and Effluent Monitoring at ANSTO Sites, 2000.* ANSTO/**E-745**.

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