Application of Radiotracer Technology to the Study of Coastal Processes

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SUMMARY: Recent progress at ANSTO in the applications of radiotracer techniques to the study of coastal processes is reviewed. Tracers are used in detailed studies of specific components of complex environmental systems and are applied to the evaluation and extension of numerical models. Examples include studies of the aggregation of sewage particles following release from ocean outfalls. The use of tracers to study the impact of storm events on bedload transport at depth has also been demonstrated.

1. INTRODUCTION:

In 1958, when the HIFAR reactor achieved criticality, radioisotope applications at Lucas Heights began expanding rapidly. By the mid-1960s radiotracing was being used in most major industrial sectors. The program expanded and matured over the intervening years to the extent that in 1999 ANSTO's interests in commercial industrial tracing were sold to the private sector. This paper will therefore focus on environmental applications.

The direction of the program has been determined by a number of factors including:

Advances in technology Although the techniques for monitoring radiotracers in the field have not altered greatly over the years, there have been major advances in a) micro-electronics, leading to enhanced instrument reliability and the ability to link detectors and associated instrumentation to global positioning systems and b) the visualisation of complex data.

Advances in numerical modelling: Applications of mathematical modelling techniques to environmental science are now very widespread and underpin much of our detailed understanding of coastal ecosystems. ANSTO's program involves the applications of tracers to the evaluation and extension of numerical codes.

Environment protection: Competition for environmental resources in a populated coastal zone is a major challenge. Indeed, the pollution of regional seas from land based activities is the first key issue for large-scale sustainability in the South East Asian region listed in the SARCS1999 *Integrated Study Science Plan* (1).

Much of ANSTO's recent work has involved the studying the fate and behaviour of particulates released from ocean outfalls (Szymczak et al (2), Zaw et al (3), Airey et al (4), (5)). The aim of this paper is to present readers with a report of the current status of the program.

2. CONTAMINANT TRANSPORT IN THE NEAR FIELD

2.1 Source Term Prediction

The prediction of a pollutant source term from its behaviour at a downstream observation point is a classical problem in tracer technology. The solution of the general problem requires inverse mathematical techniques. Because of the complexity of sewage systems, Barry *et al* (6) decided, as a first step, to address the simpler problem of predicting the response of the contaminant to a known source term. The essence of the research was to compare a conventional modelling with an artificial neural network (ANN) approach. Experimentally, the response at the Cronulla Treatment Plant to the approved low level releases of tritium in ANSTO's normal effluent was studied. In sewage systems there are countless extraneous factors which are not included in either modelling approach. Although this was a driving force in exploring the neural networks, the ANN approach did not prove superior in this study.

2.2 Near Field Dilution Factors

In most investigations of sewage released to the ocean, the tracers ^{198}Au and tritium in the form of tritiated water HTO have been chosen. ^{198}Au is a gamma emitting isotope and can be detected by field detectors deployed from the survey vessel. Tritium is the 'perfect' tracer for water and is used to obtain absolute dilution factors. ANSTO and the Unisearch Water Research Laboratory (WRL) were involved for a number of years in the radiotracer evaluation of predictive models for the transport of sewage from the deep ocean outfalls off Sydney (Pritchard (7)). The outfalls were modelled by WRL using the RMA suite of codes (King *et al* 1973 (8), King 1998 (9)).

Subsequently, the two groups were involved in tracer studies at the North West New Territories (NWNT) sewage outfall, Hong Kong. The work was undertaken for the HK Environmental Protection Department through a consultancy managed by Montgomery Watson HK and involving the survey company EGS (Asia) and the University of Hong Kong. One of the outcomes of this work was a comparison of observed effluent dilutions from tracer studies with those predicted by the near-field numerical model JETLAG (Horton *et al* (10), (11)). Good agreement was found. This enhanced the confidence with which the model could be used for predicting near field dilution factors.

2.3 Radioisotope and Fluorescent Dye Tracers

The above mentioned study also involved a comparative evaluation of the radiotracer gold-198 and the fluorescent dye tracer rhodamine-WT. The tracers were released simultaneously by ANSTO and EGS (Asia) respectively. The outputs of the scintillation probes and the fluorimeter were integrated into a central computer and linked to the navigation system. The correlations were excellent. Under the conditions of the experiment, the sensitivities of the two techniques were comparable. Special attention is therefore being paid to investigations where fluorescent tracers are not so effective. These include studies of sand and sediment transport and work in highly polluted areas.

2.4 Near Field Dispersion Modelling

To better understand the fate and behaviour of effluents released to the sea from engineered structures, a two phase turbulent flow model of the prototype of the Malabar outfall near Sydney has been developed. A Lagrangian approach is being used to track individual particles and the output is presented as a flow field or a particle density field. Advances in computational efficiencies have been made (Tu (12), Ye *et al* (13)).

3. CONTAMINANT TRANSPORT IN THE FAR FIELD

3.1 Particle Aggregation

Research is currently focused on the fate and behaviour of particulates, because they are little understood, they play a significant role in the transport of environmental pollutants and there are currently no cost-effective alternatives to radioisotopes for tracing. Complementary laboratory and field studies have been made of the behaviour of particulates released from the Burwood Beach Outfall near Newcastle NSW (Zaw et al (3), Airey et al (4) and (5)). Briefly, it was found that both the particle size, and the porosity (monitored by the fractal dimension) increased with distance from the outfall.

Enhanced porosity leads to entrainment of water within the structure. Since the particles are moving from a lower density effluent to higher density sea water, the entrained water will lead to a net buoyancy effect. This is consistent with the observation that the sewage particulates did not settle from the radiolabelled plume during the five hour field observations. There would be clear advantages in complementing radiotracer studies with emerging technologies for the *in situ* measurement of particle size distributions.

Significant success has been achieved in modelling particle aggregation in the laboratory (4). The ultimate goal is to incorporate the physical model into an environmental fluid dynamic code.

3.2 Environmental Fluid Dynamic Modelling

Far field modelling at Burwood Beach is being progressed using the Environmental Fluid Dynamic Code (EFDC) of the Virginia Institute of Marine Science (Hamrick (14)). Detailed information on the dispersion of the sewage plume over a five hour period was obtained from the radiotracer study. As indicated above, the plume rose to the surface on the day of the study. There was no evidence

for settling of the particulates. Consequently, the tracer plume could only be modelled satisfactorily by taking into account the impact of the wind field on the current patterns in the upper layers of the water column. A Lagrangian approach is being used to model the migration of the labelled sewage particles (4).

4 SAND AND SEDIMENT TRANSPORT

4.1 Sediment gauge

ANSTO has assembled a sediment gauge based on an Amdel ^{137}Cs gauge designed for the on-line monitoring of mineral slurry densities. The output of the radiation detector is linked to a marine water quality meter through the Labview® virtual instrument package.

4.2 Bedload transport

Radiotracer techniques have been used for decades to study bed load transport and applied to engineering problems associated with port development and dredge spoil dumping. In more recent times there has been a growing interest in the impact of major, infrequent events on sediment transport.

In the first instance, an attempt has been made to study the impact of storms on the migration of sediment at depth. ^{192}Ir glass with a particle size distribution matching that of the glass was used as a tracer. The ^{192}Ir (half life 74 days) was chosen because it emits gamma rays of convenient energy and can be used for studies over many months. Specifically, three vials each of 10 GBq ^{198}Ir were released 2 km from the Bondi, NSW coastline at the 68m contour.

A preliminary flume study was undertaken by the WRL to assess the strength of the current needed to mobilise the sized iridium glass beads. Wave climate data and current vectors near the surface and 12 m from the bottom were available from the Ocean Reference Station located in the general vicinity.

Observations of tracer contours were made over a nine month period with a resolution of less than 4 m. At the end of the period, the points of release of each vial could still be identified. Some dispersion was observed, but no systematic migration despite three significant storm events.

5. GENERAL IMPACT OF THE PROGRAM

5.1 Commercial

ANSTO supports commercial activities principally concerned with the applications of tracers to the post commissioning trials of sewage outfalls. Between 1991 and 1994, a series of investigations was undertaken for the NSW Environment Protection Authority and Sydney Water in association with Unisearch WRL. Over the past three years ANSTO, WRL and EGS (Asia) have contributed to a number of such trials in Hong Kong. The ultimate client is the HK Environment Protection Department with managing consultants either Montgomery Watson (HK) or Mouchel (Asia).

5.2 IAEA programs

ANSTO actively supports IAEA programs. Australia through ANSTO is a designated lead country for the IAEA/UNDP Regional Cooperative Project: *Management of the Marine Coastal Environment and its Pollution.* This project is a vehicle for building specific capabilities underpinning the application of nuclear techniques to sustainable development in the coastal zone.

6. CONCLUSIONS

Tracer techniques complement the modelling approach to the study of complex systems. Tracers permit the detailed study of individual components of a system and are particularly useful in evaluating predictive models. This was illustrated with a number of examples including the transport of effluent along sewage pipelines, as well as contaminant transport in the near and far fields.

Advances in technology have enabled the linking of radiation detectors and associated instrumentation to global position fixing systems. Much more precise data can be collected, with the consequences that a reduced level of radiotracer is frequently required and more sophisticated questions may be addressed. Examples of the latter include studies of the aggregation sewage particles in the field and of the impact of storms on the migration of sand at depth.

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