INDUSTRIAL APPLICATIONS OF RADIOISOTOPE TRACERS

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ABSTRACT

Radioisotope tracing techniques are powerful tools for analysing the behaviour of large systems and investigating industrially or economically important processes. The results of radioisotope experiments can yield important information, for example, on parameters such as flow rates, mixing phenomena, flow abnormalities and leaks.

Some examples of current AAEC research are described, covering studies on hearth drainage in blast furnaces, flow behaviour in waste-water treatment ponds, and sediment transport in marine environments.

1. INTRODUCTION

Over the past 10 years the Australian Atomic Energy Commission (AAEC) has conducted a wide-ranging program of applications of radioisotopes to solve problems of local, regional or national importance. Specifically, this work has involved the iron and steel industry, the coal industry, natural gas explorers, port authorities, water and sewerage instrumentalities and environmental agencies.

The work can be classified into three areas

- Flow studies - involving flow rate measurements, residence times leak-detection and wear;
- Environmental studies - on waste water treatment plants, sewage and and acid waste disposal, and prediction of waste-water disposal problems;
- Coastal engineering studies - examining movement of sand in rivers, estuaries and near-shore areas, dredge spoil movement and sediment gauging.

Most of the investigations are concerned with obtaining information on the behaviour of complex large systems. These data can be required for many purposes; for example, to check whether systems are working in the way they were designed, and to develop of mathematical models which are used to extend the applicability of specific observations. The development and verification of such models depends on measurements on the real system. Tracer investigations provide a vital step in this procedure.

Because radioisotopes are unstable and decay at known rates, they offer considerable advantages in a wide range of investigations requiring consecutive experiments where a suitably chosen radioisotope will effectively decay

away before the next injection. Problems of residual contamination or build-up of tracer can thus be avoided.

Another consequence of the instability of radioisotopes is the absence of most of them in the environment. Rarely will any type of radioisotope, let alone the one chosen specifically for a particular investigation, be present in a system under investigation. The radioisotope tracer will thus uniquely define material within the experiment.

If chemical species need to be monitored then the use of the appropriate radioisotope will ensure that the exact chemistry is followed.

In general, radioisotope tracers are required in only physically small amounts - milligrams of solids or millilitres of liquids - because of the large amounts of radioactivity that can be induced into many elements. The high sensitivity and stability of modern electronic nuclear radiation detection equipment also ensures that relatively small amounts of radioactivity are required for most experiments. Radioisotope tracers can be added to most systems without affecting the material balance.

Many radioisotopes emit γ-rays that can pass through significant thicknesses of construction materials such as pipes and tanks. This radiation can allow a system to be monitored externally, avoiding any perturbations that might arise from direct sampling. The γ-ray emissions also allow the monitoring of systems in real time which leads to maximum sampling efficiency and direct feed-back on system behaviour.

For all those reasons radioisotopes are generally the most appropriate and the most cost-effective means of tracing large systems.

Three current research areas of economic or industrial importance are discussed below.

2. HEARTH DRAINAGE IN BLAST FURNACES

The use of modern blast furnaces has revealed deficiencies in operating procedures developed for earlier style furnaces. In the past 15 years, there has been a world-wide and vigorous program of research to understand the behaviour of the blast furnace, particularly the furnace hearth, including such topics as improvement of coke, and analysis of hearth drainage. Much of the effort has been in the development of mathematical models and the analysis of flow behaviour in laboratory scale models using glass bead/water systems. Australia and Japan appear to be the only Western countries that have carried out radioisotope hearth-drainage experiments in blast furnaces.

Since 1979, the AAEC has carried out experiments at BHP Steel International on Nos 3 and 5 blast furnaces. The objectives are to measure the residence times of the molten iron and the molten slag in the furnace to investigate whether there is a correlation between the furnace performance and residence times. Gold-198, silver-110m and cobalt-60, in the form of wire or foil, are used to label the molten iron, and lanthanum-140 and scandium-46, in the form of oxides, are used to label the molten slag. Because of the large number of variables operating in a blast furnace a large number of experiments have to be carried out to determine how sensitive flow parameters are to changes in blast-furnace behaviour and output.

3. WASTE-WATER TREATMENT LAGOONS

Waste stabilisation ponds are used extensively throughout the world as the final stage in the treatment of sewage and other liquid wastes containing organic materials. In Australia, about 2900 hectares of ponds are in use in some 320 country areas where the effluents ultimately discharge into rivers. The correct functioning of these lagoons is, therefore, vital to the preservation of unpolluted surface waters.

In many cases, pond systems are providing effluents which do not meet today's high pollution control standards, largely because our understanding of pond function is limited rather than limits to the pond method itself. The processes that destroy pathogens and remove organic material are biological, biochemical and chemical, but the creation of favourable conditions under which these processes will proceed at the desired rates is dependent on physical conditions in the pond system. Overseas workers have cited the hydraulic (flow) behaviour of ponds as one of the major areas in which more knowledge is needed. Hydraulic behaviour, in particular, hydraulic retention time distribution (RTD) is one of the most commonly used parameters in the design and theoretical modelling of pond behaviour but is one of the least researched.

Since 1979, the Commission has used radioactive tracer techniques to study flow patterns and RTDs in sewage treatment plants. The flows have been traced using bromine-82, tritium and technetium-99m. Experiments have been set up on operating pond systems which aim

- to look for variations due to seasonal and short term weather factors,
- to improve the mathematical modelling of the RTDs,
- to correlate observed RTDs with the type of flow behaviour observed in situ tracing experiments, and
- to study the efficacy and mechanism of baffling as a means of extending retention time.

These tracer studies have shown that the flow behaviour of individual ponds can deviate markedly from the design criteria. Weather has a marked influence on the flow processes.

4. SEDIMENT TRANSPORT IN MARINE ENVIRONMENTS

A significant increase in interest in this area has occurred worldwide since continental shelf territorial rights were declared, and considerable research effort has been centred in the coastal, nearshore and continental shelf regions. In Australia, an average of $760 million is spent annually on coastal work and an average of $220 million on capital works. Many of the problems are caused by either the erosion or the deposition of sediment, and quantitative field data (to prove existing sediment transport models or to provide understanding of the basic morphological processes involved) are urgently required by engineers involved in oil and gas pipe line laying, sewage and industrial outfall design, harbour and port design and maintenance, coastal erosion control and estuarine siltation management.

A variety of radioisotope tracers, including gold-198, chromium-51, scandium-46 and iridium-192, have been used in sediment transport studies, which have included

- a study of navigation channel infill in Moreton Bay, Queensland,
- a study of estuarine siltation in Port Hacking, NSW, and
- a study of coastal erosion off-shore of Adelaide, South Australia.