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Issues of NORM in Malaysian-based industries

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ISSUES OF NORM IN MALAYSIAN BASED INDUSTRIES

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ABSTRACT

In Malaysia, the national Atomic Energy Licencing Board, AELB, closely monitors issues concerning technologically-enhanced NORM or TENORM. The AELB controls activities associated with NORM by virtue of powers given to it under Act 304 (the Atomic Energy Licencing Act, 1984) and subsidiary documents, including a now well-known technical document referred to as LEM/TEK/30, first issued in 1990 and specifically directed to the oil and gas industry. Since the late 1980's NORM-affected Malaysian-based minerals industries have been required to engage specialist radiation protection services in order to provide the AELB with frequent updates of environmental and occupational NORM levels arising from company operations. Similar requirements were imposed upon the Oil and Gas industry in the early1990's. Many observers consider the AELB trigger/reporting levels (and sampling plans) to be stringent to very high degree, the reporting levels certainly being more conservative than the exemption levels which are to be enacted in the EU in May 2000. In certain instances considerable metrological efforts must be made in order to look for significant differences between measured levels and the background level of the undisturbed environment. In addition to enforcing requirements for sampling plans the AELB also controls safe working practices, management and disposal of NORM-affected waste and sale and utilisation of affected by-product materials. Proposals for disposal must be supported by rigorous pathway analyses, requiring use of site-specific data and established computer codes such as RESRAD, an important individual dose limit being 1mSv (above background) to critical groups. The radiation protection consultants engaged by industry must be able to provide laboratory facilities for gamma spectrometry and gross-α and gross-β evaluations of liquids, solids (including flora and fauna) and gases (typically limited to air), with accreditation to ISO/IEC Guide 25 standards. Asia Lab is one of a highly limited number of radiation protection organisations in Malaysia which are able to offer such facilities This paper discusses the experiences of Asia Lab in providing service to industry. Aspects to be discussed include conduct of radiological surveys, laboratory analyses and impact assessments.

INTRODUCTION

In Malaysia, prior to the enactment of the Atomic Energy Licencing Act of 1984 (Act 304), all radiation protection issues in the country were managed by the Ministry of Health, through its Radiation Protection Unit. The Ministry of Health remit included control of NORM in the minerals mining and benefication industries as well as use of radiation sources in industry, including for instance applications of radiation sources in semiconductor fabrication and the oil and gas industry (through powers given to the Ministry under the Radioactive Substances Act of 1968). The1984 enactment of Act 304 provided for the establishment of an Atomic Energy Licencing Board, with responsibility in areas of radiation protection other than medical applications; the latter, for all intents and purposes, has remained part of the remit of the Ministry of Health.

With the establishment of the AELB immediate attention was given to the management of radiation protection issues involving NORM. It is to be noted here that there has been a long history (in excess of 100 years) of tin mining in Malaya and Malaysia and, as a result, a number of associated radiation protection issues have evolved, particularly in downstream processing industries. Udompornwirat (1993) has given a review of radiological hazards associated with the processing of tin by-products and discards in South East Asia. Hart and Levins (1988) have reviewed management of NORM wastes arising from the processing of rare-earth minerals, while Cooper et al (1981) and Cooper and Williams (1984) have looked at issues concerning NORM in association with production of titanium dioxide pigments. Of associated interest is the conduct of impact assessment in respect of utilisation of Gypsum by-product (O'Riordan et al, 1972) and other by-products. The radiological hazard in working with ores containing NORM at elevated levels has been examined in some detail by Dixon (1984).

Regulatory control of NORM-related activities in Malaysia now extends to industries engaged in tin smelting, utilisation of materials containing radioactive accessory minerals (particularly those which are associated with monazites, titanium dioxide and zircon), production of drilling muds (barytes), grits for grit-blasting operations and oil and gas operations. In addition regulatory control is also placed upon future utilisation of by-product materials such as gypsum and iron oxides and disposal or utilisation of discard materials such as tin slag and the sludge/scale resulting from oil and gas operations.

This paper does not deal in any direct way with control of workers and safe working procedures in establishments where NORM is to be found. Suffice it to be noted that these issues are stringently controlled by the AELB. Note also that, in principle, all NORM-affected industries in Malaysia require an operating licence from the AELB. One of the current exceptions to this is the oil and gas industry, this being a situation which is understood to be receiving the consideration of the regulators. Licenced industries are subject to routine and surprise inspection by the AELB.

The issues to be focused upon herein concern conduct of radiological surveys, laboratory analyses and impact assessments, in support of the demonstration of compliance with AELB reporting levels. These levels are such that they often imply rather detailed efforts in attempting to yield results which, in other circumstances, might otherwise be recorded as being below the lower limits of detection. The experience of the author in working with industry in attempting to satisfy the needs of such a regulatory system may be of interest to European industry and the radiation protection community, given that in May, 2000 the EU is to enact a new and generally more conservative basic safety standard which includes exemption levels for radionuclides found in NORM. In Malaysia NORM-affected industries continue to thrive within a system of Health, Safety and Environment policies and regulations which are intended to provide for the greater benefit of all. However the implementation of these policies and regulations have not been without their attendant issues and problems, some of which are touched upon below.

AELB DATA REQUIREMENTS

THE MINERALS INDUSTRY

In the relevant industries, it is incumbent upon the operator to conduct and make available the results of frequent comprehensive radiological surveys. The AELB requires that use be made of specialist radiation protection personnel for this task. The data requirements are such that surveys must be conducted both on- and off-site, values being obtained at sampling stations defined by the AELB (based on meteorological and demographic factors, most usually in terms of wind- rose data, land utilisation, surface and ground-water location). In some cases data have been required from sampling stations within zones located as far as 20km away from the plant; while this may be exceptional, the defining of sampling stations 5km distant from the plant is not. During the initial stages of such a series of surveys the frequency of taking data is typically once per month, generally becoming less frequent (perhaps once every two to three months) once it is demonstrated that impact controls are effective, as reflected by the results themselves. For sufficiently large data sets Asia Lab generally provides annual summaries for each of the monitored parameters, the results being presented in two ways, viz: (i) as a frequency distribution, and (ii) as a function of time. A general scenario for any monitored

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facility is accumulation of data over a period of say two years (to make a total of perhaps 24 individual data sets if the frequency of surveys is once per month). During this time the plant will typically hold a temporary operating licence. If significant differences are not observed between values of data at say the site perimeter and at more distal sampling stations (where values are more than likely to be indicative of the undisturbed environment) then it is this authors experience that the AELB are amenable to relaxation of the survey regime in terms of frequency, monitored zones and numbers of sampling stations in each zone. At this time a full operating licence might also be granted. In the authors experience many of the summary frequency distributions for operational data take on the form of log-normal distributions, indicating lack of accumulation of activity in the environment (see for instance, Bradley, 1995). Such a situation is sometimes not observed in plant areas where NORM-affected storage ponds and pits are to be found.

For new enterprises a series of pre-operational surveys are often required, particularly for those industries intending to set-up on green-field sites bordering upon residential areas. The rationale is clear; data from baseline surveys allow the impact of operations to be better judged. For a typical pre-operational survey, detailed efforts are needed in attempting to satisfy the range and reporting levels of parameters required by the AELB. As an instance, in a recent series of surveys performed by Asia Lab, prevailing activities in air were required to be identified and quantified, necessitating use of a high volume air sampler (sampling at a rate of $70m^3$ per hour over a continuous period of 24 hours at each specified sampling point). Use was made of fibreglass air-filters to ensure that low backgrounds were obtained. In addition to data from gamma spectrometry and gross α/β analyses, U and Th levels were also required to be reported by means of instrumental neutron activation analysis (irradiation and evaluation being carried out at the national research reactor centre). The results of this particular series of surveys are to be presented by the author at a Regional Conference of the International Radiation Protection Association (IRPA, Prague, 8-12 September, 1997).

A radioactive balance analysis (RBA) is also a requirement of large scale minerals processing industries. The intent is to seek to match the radioactivity of the feed material with that of the outputs, including waste streams and effluents. This is intended to provide industry and regulators with a clearer understanding of output rates, also indicating the efficacy of engineered controls or of need for improvement in their efficiency. In some circumstances, including variations in the activity of the feed material and non-uniformity in the process line, the results of cross-sectional studies of the process line become unreliable, the fate of 'typical' feed material being poorly represented. This can be an unfortunate outcome, since the more representative longitudinal analysis is rathermore time consuming.

For industrial plant, in which one or more stacks form part of the effluent control system, it is worth noting that on at least one occasion the AELB has required that use be made of a gaussian plume model in assessing impact of dispersal (see for instance Clark, 1979). The AELB has also considered need for modelling of the effects of more complex dispersion situations, as caused for instance by building wakes and specifics of the terrain. However, to-date the author knows of no case in Malaysia in which this has been made a condition of an impact assessment.

For site-remediation, national clean-up criteria have only been established for land which has been exclusively assigned to industrial use. In this situation the limiting annual dose to individuals on-site and to critical groups has been set at 1mSv above background. Use of screening radiological impact assessments are no longer viewed by the Board to be acceptable and full computerised modelling using site specific data is required. The RESRAD code (US DOE, 1993), developed at Argonne National Laboratory, has already been used in Malaysia in a number of such studies. Clean-up sampling plans are also being devised, international formulations being used as the guidance for such efforts; the report of Wolbart et al (1996) is particularly pertinent in this latter respect. The time-scales associated with gamma-spectrometry of soils samples and the programming of earth removal works are in conflict with each other. Consideration of the issue of in-growth and establishment of secular equilibrium is actively being pursued in response to actual needs.

OIL AND GAS FACILITY OPERATORS

The AELB in collaboration with PETRONAS (the National Petroleum Company) have introduced guidelines on radiological monitoring for oil and gas production-sharing companies which operate in Malaysia and Malaysian waters. The first set of guidelines (which in practice seem to have assumed the nature of imperatives) were made available in a Technical Document issued by the AELB in September 1991(LEM /TEK/30 SEM.1). The fundamental need laid out in this document was for production-sharing companies to furnish the AELB with a nominal 10 sets of survey data, the series of surveys being spread out over a period of five years (at a frequency of one compete survey of facilities every six months). The data requirements relate to the situations which prevail during routine operations (viz on a sealed process-line), although the obtaining of specific data during maintenance or workover operations has also been encouraged. Data taken during maintenance (as in for instance in association with vessel entry) provides an indication of the value of routine monitoring, particularly within the context of being able to anticipate the appropriate level of radiation protection required for the work.

The scope of the routine surveys has included all manned facilities both on-shore (crude oil terminals and supply bases) and offshore, as well as unmanned platforms (jackets, satellites, off-loading points/tankers). The intent of the survey regime has been to allow the AELB to obtain a radiological datum line for oil and gas production facilities. Facilities exempted from the survey include gas-venting facilities. Towards the end of 1996 a first revision of the Technical Document LEM/TEK/30 was issued (LEM/TEK/30 SEM.2, September 1996), being partly in response to experience obtained to-date. The views of the production-sharing companies were sought and taken into account in producing this revision.

A tremendous amount of effort has and continues to be put into conduct of the five year survey of NORM levels during routine operations. Asia Lab graduate staff, typically leading a team of two persons or more, continue to survey every single structure or facility identified as part of the survey regime, each structure/ facility being surveyed twice per year. Indeed, the AELB may now possess what could be the most detailed regulatory-agency NORM characterisation of its kind (the parameters required by the AELB are recounted below). In order to manage the volume of data being generated the AELB has devised a standard report format in a form suitable for its computerised information system. The report format is based on a schematic of the process-line for every operating facility, the sampling points being identified along the process line. Every report submitted to the AELB is required to be presented in both hard-copy and electronic form.

The parameters and reporting levels included in the original LEM/TEK/30 document, comprise of external gamma dose-rate (0.5□Sv h^{-1} inclusive of background), surface contamination (0.04 Bq cm^{-2} for alpha emissions, 0.40 Bq cm^{-2} for other emissions), Rn and Tn progeny levels (0.01WL and 0.02WL respectively), airborne activities of ^{238}U, ^{232}Th, ^{226}Ra, ^{228}Ac and associated gross alpha and beta levels for suspected dusty working environments (0.01 Bq m^{-3} for ^{238}U, 0.002 Bq m^{-3} for ^{232}Th). Reporting levels have not been specified for other NORM radionuclides but the DAC's for these are provided in the Basic Safety Standard which forms part of Act 304. In addition to the foregoing, LEM/TEK/30.Sem1 has also required report of the total specific activity (TSA) of scale and sludge (0.1 Bq g^{-1} above prevailing background). As with at least one other regulatory authority (see for instance Anderson, 1990) the AELB have required TSA to be quoted assuming secular equilibrium, viz TSA = (6 x specific activity of ^{226}Ra) + (8 x specific activity of ^{228}Ac), ^{226}Ra and ^{228}Ac characterising the presence of ^{226}Ra and ^{228}Ra progeny in the ^{238}U and ^{232}Th chains respectively. Anderson (1990) has discussed the basis of using the factor of eight rather than nine in assessment of the contribution to activity from ^{228}Ra. Note that for TSA account is only taken of those progeny contributing significantly to the total activity following the elapse of several half-lives, an issue which again has been discussed by Anderson (1990).

A widely held view is that there should be little expectation for the presence of elevated levels of U in sludge and scale. As such the associated gamma emission of ^{226}Ra at 186.1 keV is generally of sufficient prominence, and should suffer minimal interference from the 185.7 keV emission of ^{235}U, that it can be used directly in evaluating the presence of ^{226}Ra. For the minerals benefications industry this is most certainly not the case for affected soils and interference from the ^{235}U emission at 185.7 keV needs to be taken into account in accurate appraisal of the content of ^{226}Ra (Harbottle and Evans, 1997). The radionuclide ^{228}Ac is used to evaluate the presence of ^{228}Ra; the issue of interfering emissions does not arise for this radionuclide.

The first revision of LEM/TEK/30, viz LEM/TEK/30.SEM 2, incorporates few changes in the monitored parameters or reporting levels. The main difference, in as far as the conduct of the routine surveys is concerned, is removal of a requirement for monitoring of ^{220}Rn (radon) and ^{222}Rn (thoron). Explicit mention is also made of a requirement for the use of advanced computational methods (one example of which is the RESRAD code) in impact assessments of disposal of affected materials. Removal for the requirement of the routine monitoring of radon progeny perhaps results from discussions between regulators and industry concerning the value of measurements made on a closed process line, particularly in open offshore environments. In respect of impact assessments, these are required to demonstrate that engineered containment (sometimes referred to as and engineered cell) of discard materials is sufficiently effective in order that the dose to critical groups is less than 1mSv (use of the natural materials clay and zeolites find particular favour, by virtue of their high absorptive capacities for radionuclides and also because of an ability for self-healing following possible fractures resulting from earth movement). It would appear, in using engineered cells for containment of NORM, that doses which are a small fraction of the ceiling dose of 1mSv can be achieved. Given the verity of modelling, implied annual risks of health detriment from such situations would be significantly less than 1 in 100,000, use being made of risk factors published in ICRP 60. In all such impact assessments the AELB requires that use be made of site specific data, including assessment of transfer coefficients K_d for soils forming part of and underlying the engineered cell.

ACCURACY AND PRECISION OF DATA: ARE ASIA LAB RESULTS REPRESENTATIVE?

Laboratory practices, equipment reliability and instrumentation capabilities (for both *in situ* and lab analytical measurements) have particular prominence within the monitoring regime outlined above. In this respect Bradley (1995) has reported a list of Asia Lab capabilities for both *in situ* and lab analytical equipment. Asia Lab capabilities compare favourably with industry standards in terms of lower limits of detection (see for instance, Cox and Guenther,1995). The practices followed by Asia Lab for sampling and analysis are as laid out in the Laboratory Procedures Manual for Oak Ridge Associated Universities Environment Survey and Site Assessment Programme, Revision 5 (February, 1990) and the IAEA Technical Report, Series No. 295 'Measurement of Radionuclides in Food and the Environment: A Guidebook' (1989). Asia Lab gained national accreditation to ISO/IEC Guide 25 standards in 1991, a status which it has since maintained. Intercomparison exercises between Asia Lab and other laboratories located in Malaysia, UK, USA, Canada and Australia are on-going. Such intercomparisons have included gamma spectrometry of various media and TLD evaluations of gamma dose-rate; although these results provide a certain level of reassurance the company is not complacent and continuous quality improvement is practiced.

Long-term assessments of external gamma dose rates are obtained using integrating devices, as in for instance TLD's, placed *in situ* for a period of say 30 days. Batch to batch variations are one characteristic of TLD's and for this and other reasons Asia Lab maintains a series of controls. Within the past twelve months Asia Lab has participated in the US DOE 11th International Intercomparison of Environmental Dosimeters, the results of which are expected to be published; preliminary findings from this exercise are encouraging.

In respect of analysis of NORM in gas plants, to-date their has been no requirement by the AELB for the conduct of α-spectrometry. As a consequence a number of issues remain practically unexplored, including the possibility of there being the presence of elevated and unsupported levels of ^{210}Po.

Asia Lab has maintained an on-going dialogue with the AELB regarding Board expectations for the value of the data which is being reported. In some situations Asia Lab finds AELB reporting levels to be such that both precision and accuracy of measurements become critical factors in deciding whether measured levels are in fact reportable. Particular examples include *in situ* and wipe test evaluations of surface contamination and use of personal air samplers - the latter being used to obtain eight-hour grab samples of air, volumes being obtained at physiologically realistic breathing rates. Concerns for both are detailed below.

SURFACE CONTAMINATION MONITORING

Suitable certified large area contamination sources at the surface emission rates which are associated with AELB reporting levels are not available. As such surface contamination monitors have not been type-tested (with traceability) for the application to which they are being put (NORM contamination at levels of < 1 Bq cm^{-2}). In the absence of suitable calibration sources at the level of 1Bq cm^{-2} and below Asia Lab has has had no option but to fabricate its own temporary 'transfer'reference sources. For this purpose thin layers of iron oxide have been formed on suitable planchettes, from samples of iron oxide obtained during Asia Lab surveys of the titanium production industry. Evaluation has then been undertaken using the Asia Lab low background α/βcounting system (LB 5500, Oxford). Finally comparison is then made between evaluations of activity obtained using the low background α/βcounting system and the surface contamination monitors. Asia Lab experience is that under laboratory conditions an ESP-2 surface contamination monitor has a threshold for detection of the order of 0.03 Bq cm^{-2}, this being comparable with the reporting level itself. In monitoring of surface contamination at survey sites Asia Lab has made use of the Student t-test in deciding whether the results of measurements differ significantly from background.

For the process of testing of surface contamination monitors (and also dose-rate meters) use is made of the UK Health and Safety Executive guide, HS(G)49. An issue which remains unresolved is that of having realistic NORM calibration sources able to accommodate the needs of the minerals and oil and gas industry.

In the absence of any detailed knowledge of the relative proportions of fixed and loose contamination a wipe-test can only really be regarded as being able to provide an indication of the presence of contamination. Typically such a test will involve use of a 10% default pick-up efficiency. At values of twice background the wipe test can be a reliable indicator of contamination but at values approaching reportable levels it would be inappropriate to place reliance upon the method.

AIR SAMPLING:

In respect of calibration of the flow rate of personal air samplers (for these Asia Lab combines a sampling head with a Flow-Lite Pro portable pumps, Mine Safety Appliance Co, MSA,Pittsburgh, PA), use is made of an MSA Optiflow, Model 655, Primary Flow Standard. Grab sampling of 960 litres of air over a nominal period of eight hours (this as practiced by Asia Lab) is found to be sufficient to yield useful detection capabilities for gross-α and gross-β levels, the former being the parameter which is most directly of interest in radiological assessment. Values which have been typically obtained by Asia Lab in offshore surveys accord with those reported by Thayer and Racioppi (1994) . The same 960 litres of air is insufficient for sensible gamma spectrometric analyses (i.e. above MDA), a situation which again accords with the observations of Thayer and

Racioppi.

INTRINSICALLY SAFE INSTRUMENTATION

A further confounding issue in efforts towards seeking high reliability data results from limitations placed upon use of non intrinsically safe equipment. Such limitations on the use of equipment is particularly obvious in the case of the oil and gas industry. Even with facilities which are intrinsically safe, absolutely all of Asia Lab's on-site evaluations in the oil and gas industry are conducted using a hot-work permit, the survey team also being accompanied by a person designated by the facility operator as gas-tester. Among the intrinsically-safe instruments which Asia Lab makes use of are hand-held dose-rate meters and personal air samplers. Note that while great sensitivity to activity in dust can be obtained using high-volume air samplers, also allowing gamma spectrometric analyses, such instruments would have highly restricted application within the oil and gas industry.

In an effort to make increasing use of intrinsically safe devices Asia Lab has also evaluated electret devices in the monitoring of Rn and Tn progeny levels. Requirement for an integrating period of several days or more, combined with the performance problems experienced by Asia Lab in the use of these devices in high humidity environments, has meant that the company continues to favour use of RDA-meters and a modified Kusnetz method (Kusnetz, 1956).

SUMMARY

Work which involves NORM-affected material can be well managed within the context of engineered controls, safe-working procedures and monitoring. Here it must therefore be mentioned that many of the Asia Lab clients have their own internal HSE policies and default reporting levels for NORM. In the absence of national legislative imperatives, such internal controls continue to ensure that evaluation of NORM is undertaken within the working and surrounding environment.

The AELB have instituted a rather stringent set of NORM guidelines, some aspects of which continue to be discussed in various meetings. NORM-affected enterprises have responded accordingly by initiating comprehensive testing. The stringency of reportable levels has given rise to a range of technical problems, some of which have been resolved through discussions between the various parties. A number of other technical and radiological problems remain unresolved, as discussed herein. The requirements for conduct of an impact assessment as a precursor to disposal of affected waste is now clear and good experience has been gained in a number of exercises. Site remediation prior to abandonment of a site is an issue which is currently being studied in detail. Use of economically valuable NORM affected by-products remains an unresolved issue.

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