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The Impact of Open Water Management System in Amang Processing on the Water Quality and ^{238}U and ^{232}Th Activity Concentrations in Sediment and Water

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Abstract: The processing of amang or tin-tailing in Malaysia has been an important on going radiological as well as environmental issues in Malaysia. Large volume of water is used in the extraction of valuable minerals from amang and it has become a potential source of environmental pollution depending on how the water is managed. An environmental impact study of one such amang processing plant using the open water management system was conducted. Four sampling locations were identified; amang effluent containment pond - before the water is discharge into the river (C1), effluent discharge point - in the middle of the river (C2), the river upstream (C3) and the river downstream (C4). Water Quality Indices and activity concentrations of ^{238}U and ^{232}Th were used as indicators of environmental and radiological impact of such water management system to the immediate water body. Results obtained showed that such water management system does not appear to impact the environment and may be the answer for some mitigation measures to reduce environmental problem related to effluent discharge from such plants. This study discuss current finding and provides cautionary statements to ensure conservation of the environment.

Key words: Amang, open water system, water quality index, Uranium-238, Thorium-232

Introduction

Amang a by-product of tin mineral processing has been found to contain valuable minerals such as ilmenite, zircon, monazite, xenotime, columbite and struverite that are of high demand in the production industry. Such minerals also contain naturally occurring radio nuclides as part of their chemical properties. During the extraction process for these minerals the intrinsic radio nuclides are technologically enhanced producing what is termed Technologically Enhanced Naturally Occurring Radioactive Materials (TENORM). Studies done by the Atomic Energy Licensing Board of Malaysia have shown that the uranium and thorium concentrations vary in monazite, xenotime, zircon and ilmenite (AELB, 1991).

The presence of radio nuclides makes amang and some of the valuable minerals a potential radiological risk to man (Hamid ***et al.***, 1994; Zaidan and Ismail, 1995) and the environment (Ismail ***et al.***, 1996; Ismail, 1997; Ismail and Mazlin, 2002. Valuable minerals containing TENORM such as

zircon and ilmenite stored outside the amang plant has the potential to be washed away by rain and carried off by wind and consequently polluting the environment (Hu ***et al.***, 1995). The decay of uranium and thorium also release radioactive gases of radon and thoron respectively that posed radiological hazard when inhaled.

In amang processing large volume of water is used in the wet gravity separation process. Depending on the type of water management system used, the effluent from the plant could be either released into the environment or recycled. Whichever system used, there is a potential of impacting the environment. A study was carried out to evaluate the radiological as well as environmental impact of amang processing using the open water system.

Material and Methods

Study parameter

A study was conducted on an amang processing plant using the open water system. In an open water system, fresh water is drawn from a nearby river, used in the wet gravity separation in the amang plant and subsequently released back into the same river (Ismail ***et al.***, 1999). In this study both water and sediment samples were studied. The parameters studied for water samples were Water Quality Index (WQI) and natural radioactivity concentration while for sediment and amang samples the parameter was natural radioactivity concentration. For the Water Quality Index, the parameters considered were the pH, Dissolved Oxygen (DO), Ammoniacal Nitrogen (AN), Suspended Solid (SS), Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD). Radio nuclides measured in this study were ^{238}U and ^{232}Th.

Sampling stations

Water and sediment samples were collected along the Senudong River, close to an amang processing plant at Kampar, Perak, Malaysia. Four sampling stations were identified, that are, amang effluent containment pond - before the water is discharge into the river (C1), effluent discharge point - in the middle of the river (C2), the river upstream (C3) and the river downstream (C4). C3 and C4 are about 75 m from C1. There are no inflow of water into the river between C3 and C4.

Analysis and Instrumentation

The analytical techniques used for determining parameters used in WQI were as given by HACH Water Analysis Handbook (1997). The ammoniacal nitrogen was measured using spectrophotometer HACH Dr/2000. Nessler Method was used in determining the concentration of ammoniacal nitrogen in the water sample. Photometric method was used in determining the suspended solid in water samples while chemical oxygen demand was determined using Reactor Digestion Method by HACH. The Biochemical Oxygen Demand was determined using dissolved oxygen meter. Biochemical Oxygen Demand was calculated for BOD 3 days content (BOD_3).

WQI was calculated based on the Pollution Index of the Department of Environment (DOE) Malaysia. This DOE-WQI was calculated using the formula incorporating the subindices of pH, AN, SS, DO, BOD and COD as shown below (DOE, 1979)

$$WQI=0.12\ SipH + 0.15\ SIAN + 0.16\ SISS + 0.22\ SIDO + 0.19\ SIBOD + 0.16\ SICOD$$

The determination of natural radioactivity, concentration of ^{238}U and ^{232}Th was done using direct counting techniques with a HPGe detector. The calculations were based on the secular equilibrium equation where, the standard activity counted:

$$A = Wp = \lambda N$$

$$W_p = \frac{h\ 2}{t_{½}} \left[\frac{W\theta}{M}\ A_N\right]$$

where

W_p = Standard activity concentration (Becquerel per Litre = Bq/L)
$t_{½}$ = Radionuclide half-life (second =s)
W = Standard mass used (gram=g)
θ = Natural overflow of radionuclide
M = Relative molecular mass (g)
A_N = Avogadro's number (no. of atom/mol)

$$\frac{As}{Ap} = \frac{Ws}{Wp} \times \frac{Vs}{Vp}$$

$$Ws = \frac{As}{Ap} \times \frac{Vp}{Vs} \times Wp$$

where

Ws = activity concentration @ radionuclide mass in sample
Wp = activity concentration @ radionuclide mass in standard
As = nuclide activity in sample (count per second = cps)
Ap = nuclide activity in standard (cps)
Vs = sample volume (mL)
Vp = standard volume (mL)

Similarly for the sediment and amang samples the calculations were based on the above except that

Vs is replaced by Ms-sample mass and
Vp is replace by Mp- standard mass.

IAEA-375 soil was used as standard reference material.

Results and Discussion

DOE-WQI is graded as follows

0 - 59, contaminated; 60 - 80, slightly contaminated; 80 - 100 clean. Based on the data obtained and the grading system used, it was concluded that amang processing using the open water system did not appear to contaminate the adjacent water body, i.e. the river. All stations recorded a WQI ranging from 81.2 - 95.9. Even WQI of water in the plant (C1) and at the point of discharge (C2) showed WQI that were considered clean. Studies carried out in 1998 also showed similar water qualities. The WQI at these same locations, i.e. S1 (currently C1), S2 (currently C2), S3 (currently C3) and S4 (currently C4) were 79.2, 84.0, 91.3 and 86.4 respectively (Table 1). Detailed analysis of each parameter used in the determination of WQI revealed that at all locations except C1, all parameters measured were within the acceptable national limits for standard B for industrial effluent discharge (EQA, 1978) and Class I of the Interim National Water Quality Standards of Malaysia. Standard B provides parameter limits of effluent discharge into other inland water except water catchment areas. However, the total suspended solids at C1

Table 1: WQI of water sampled at different locations and times

	Subindex (SI) (%)						
Stations	SipH	SIAN	SISS	SIDO	SIBOD	SICOD	WQI
S1 (I)	87.34	38.02	56.4	100	97.4	84.5	79.2
C1 (II)	96.10	90.00	93.0	100	99.1	95.0	95.9
C1 (III)	39.25	90.00	78.0	100	91.5	94.0	85.1
S2 (I)	87.70	25.65	85.1	100	98.7	95.1	84.0
C2 (II)	86.03	94.20	93.0	100	94.5	91.0	93.9
C2 (III)	61.07	64.52	61.0	100	89.8	79.0	78.5
S3 (I)	91.64	58.28	95.7	100	99.1	96.4	91.3
C3 (II)	89.43	96.30	96.0	100	94.1	96.0	95.8
C3 (III)	88.06	94.20	95.0	100	85.6	91.0	92.7
S4 (I)	87.80	34.45	89.4	100	98.7	97.8	86.4
C4 (II)	48.46	87.90	76.0	100	90.7	95.0	85.6
C4 (III)	73.32	67.89	59.0	100	86.4	90.0	81.2

Sampling date: (I) = 1998 (II) = 18/7/2001 (III) = 8/10/2001

WQI Grades:

0-59 Contaminated 60-80 Slightly contaminated 80-100 Clean

Table 2: Activity and Mass Concentrations of Uranium-238 and Thorium-232 in water samples

	Time of samplings: 18-07-01		18-07-01	
	Activity Concentration (Bq L^{-1})		Mass Concentration (mgL^{-1})	
Station	U-238	Th-232	U-238	Th-232
C1	26.84±1.55	26.30±0.77	6.58±0.38	6.45±0.19
C2	41.86±2.18	35.34±1.18	10.26±0.53	8.67±0.29
C3	35.42±2.08	34.52±1.13	8.68±0.51	8.47±0.28
C4	33.28±2.12	35.34±1.01	8.15±0.52	8.67±0.25

Table 3: Activity and Mass Concentration of ^{238}U in Sediment and Amang samples

Station/Minerals	Activity Concentration (Bq/kg)	Mass Concentration (mg/kg)
C1	136.7±3.1	10.42±0.23
C3	151.4±2.8	11.54±0.21
C4	90.9±1.9	6.93±0.15
Ilmenite	318.9±2.6	24.31±0.20
Monazite	1856.5±9.3	141.52±0.71
Xenotime	6911.1±11.7	526.83±0.90

Table 4: Activity and Mass Concentration of ^{232}Th in Sediment and Amang samples

Station/Minerals	Activity Concentration (Bq/kg)	Mass Concentration (mg/kg)
C1	126.1±1.6	31.99±0.39
C3	476.6±2.6	120.88±0.66
C4	109.3±1.3	27.72±0.33
Ilmenite	142.7±1.2	36.19±0.31
Monazite	10287.0±9.3	2609.42±2.35
Xenotime	3733.1±6.0	946.92±1.52

Table 5: Total selected heavy metal extracted consecutively and averaged at study stations

Heavy Metal	Concentration (μg/g) C1	C2	C3	Total extracted (μg g^{-1})	Average (μg g^{-1})
Cu	14.3	32.11	9.29	56.13	18.71
Pb	70.22	60.51	31.38	162.11	54.04
Zn	23.49	53.37	34.93	111.78	37.26

(80 mg L^{-1}) were slightly higher than the Sewage and Effluent Standard A (50 mg L^{-1}). Standard A provides parameter limits of effluent discharge into inland waters in catchment area. The lower total suspended solids at C2 indicates the effectiveness of a silt trap placed after C1 and just before C2.

Table 2 shows the activity and mass concentrations of ^{238}U and ^{232}Th in the water samples at all locations. The concentration of ^{238}U ranged from 26.84 - 41.86 Bq L^{-1}. Although there were differences in activity concentrations among stations, their values were lower than their respective activity concentrations in sediments at the same stations and were even much lower than those in valuable minerals such as ilmenite, monazite and xenotime (Table 3). Similar conclusion may be made for ^{232}Th (Table 4). This was expected since such radio nuclides are part of the chemical structure of the minerals (e.g. Monazite [(Ce, La, Y, Th)] PO_4, Zircon [$ZrSiO_4$]) and are not easily released from the minerals except under harsh conditions (Hart ***et al.***, 1993). It may be concluded that radio nuclides contamination of sediments are largely due to minerals containing NORM found in sediments and not from free radio nuclides dissolve in the water.

Significantly higher activity concentrations of ^{238}U and ^{232}Th were recorded in sediments at station C3 (river upstream) compared to other stations Table 3). This may be attributed to the presence amang and processed minerals stockpiles in an open space near the river at C3. Rain and wind could easily wash these radioactive containing minerals into the river at C3.

Another finding from this study is the difference in activity concentrations of radio nuclides in ilmenite, monazite and xenotime. Xenotime had the highest activity concentrations for both radio nuclides followed by monazite and ilmenite. This information is pertinent to radiological impact assessment to the environment, especially the immediate water body. Their relative concentrations in amang and the types of mineral stockpiled outside the plant and exposed to rain and wind may determine the levels of radioactive released into the environment as shown from the data collected at C3.

From parameters studied and all the data gathered in this study and those carried out in 1998, it is interesting to note that the use of Open Water Management System actually did not contaminate the immediate water source, i.e. the river. The use of a silt trap to trap suspended solid before discharging them into the river has helped contain the potential increase in total suspended solids in the river. The use of limestone boulders in the water at C2 may have helped reduced the water pH there and downstream.. However, it should be pointed out that amang soil varies in pH. The low pH levels of water at C1, C2 and C4 at this time of measurement may be attributed to a low pH in the amang soil being processed. Although mitigations measures in placed appear to help contained any environmental impact to the immediate water bodies, continuous monitoring of discharge must be maintained so that existing environmental status is conserve while allowing such economic activity to continue.

It can be concluded that current studies showed that the water discharged from the amang plant using the Open Water Management System did not have any significant impact to the water as well as the sediment qualities in Senudong River. The WQI were within the clean grade of the DOE-WQI grade. All water quality parameter values taken from the river were lower than the limits provided for by standard B of the EQA (Industrial Effluent and Discharge) Regulations and those of class III (INWQS). The concentration of ^{238}U and ^{232}Th in the river sediment suggested a possible contamination of the river not related to water gravity separation but rather by the manner amang and the minerals were stockpiled outside the plant and near the river.

References

AELB., 1991. Radiological hazards assessment at mineral processing plants in Malaysia. Atomic energy Licensing Board of Malaysia. LEM/LST/16/pind. 1.

DOE., 1979. Third Schedule Environmental Quality (Sewage and Industrial Effluent) Regulations.

HACH., 1997. Water Analysis Handbook, 3rd Edition, pp: 825-1122. Colorado. HACH Company.

Hamid, A.L., T.A.R. Mohd, K. Amran, A.H. Mohd, 1994 Radiological Hazards Assessment at Mineral Processing Plants in Malaysia. Radiological Hazards in Tin Mining and Heavy Mineral Processing. Proceeding of SEATRAD/BGR. Malaysia, pp: 32-40.

Hart, K.P., R.A. Day, P.J. McGlinn, D.M. Levins and R. Stanojevic, 1993. Removal of radioactivity from mineral sands products. Proceeding of the XVIII International Mineral Processing Congress, Sydney, Australia 23 - 24 May. Australian Institute of Mining and Metallurgy.

Hu, S.J. and S. Kandaiya and T.S. Lee, 1995. Studies of the radioactivity of amang effluent. Appl. Radiat. Isot., 46: 147-157.

Ismail, B., M. Mahani and R. Puvaneswari, 1996. Cytotoxicity of soil containing amang measured using ***Setcresea purpurea***. 4th Symposium of Applied Biology, UKM, Malaysia, pp: 35-36.

Ismail, B., 1997. Radiological and Biological Impacts of amang a TENORM industry in Malaysia. Proceeding of International Nuclear Conference. INC'97, pp: 79-88.

Ismail, B., M.B. Mokhtar and B.H. Tan, 1999. Impact of amang processing on the water quality of an immediate water body: A case of a recycling water system. Sci. Int. (Lahore), 11: 1-4

Ismail, B. and B.M. Mazlin, 2002. Managing environmental risk to immediate water bodies associated with amang processing industry. Proceedings of the Regional Symposium on Environmental and natural Resources vol.1. Omar, R. Ali Rahman, Z, Latif, M.T., Lihan, T and Adam, J.H. (eds). Malaysia

Zaidan M.K. and B. Ismail, 1995. Radiation-induced chromosomal aberrations among TENORM workers : amang- and ilmenite-processing workers of Malaysia. Mutation Research, 351: 157-161.