GROUND WATER MOVEMENT STUDIES IN RADIOACTIVE
WASTE STORAGE SITE - TROMBAY

by
V. B. Godse and Mahesh Singh
Waste Treatment Division

BHABHA ATOMIC RESEARCH CENTRE
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1. INTRODUCTION

Every industry produces some waste and various methods are adopted to dispose it of in a suitable manner so as to cause minimum pollution to the surroundings. Because of peculiar behaviour and highly toxic nature, the disposal of radioactive wastes pose a special problem. These wastes, depending upon their chemical and radiochemical properties, are treated and finally contained or disposed of to underground environment under controlled conditions to minimise health hazards to the surrounding population.

Before disposing them of to the ground, it becomes necessary to study the sub-surface geological and hydrological conditions and select a suitable area, where they are likely to remain till their activity decays to permissible limits.

2. PHYSICAL FEATURES OF THE SITE

2.1. Location and general description

The area is located on the southern slope of the Trombay hill about 1 km further north of the major laboratories and plants. Before levelling, the area was highly undulated with occasional pits, drained by two nallas, cutting diagonally through it (Fig.1). The area was levelled to a uniform slope towards the Trombay bay and the nallas have been diverted along the eastern and western boundaries of the area. Both the nallas are dry for the major part of the year except the rainy season. Fig.2 shows the lay-out of the radioactive waste storage site with bore hole locations, after levelling.

2.2. Geology of the Area

The Trombay island is composed of basic igneous rocks and is surrounded on all sides by alluvium and marshy swamps. Five different rock types occur in the area indicating different phases of igneous activities. But by
far the most important and abundant rock is the typical basalt which occurs as horizontal flows forming the bulk of the Trombay hill.

The radioactive waste storage site covers an area of about 50,000 m² at the foot of Trombay hills (905 and 334 ft) between the contours of 20 ft and 90 ft. (Fig.3).

2.3. Surface Geology

The area is composed of typical basalt having a thin covering of reddish brown clayey soil with a small amount of organic matter. The basalt at the surface has undergone weathering of varying intensities with colour variation from dark brown to yellowish brown, which crumbles easily. At a few places in excavations, clay bands of deep red and yellowish colour have been observed. The fresh basalt rock is dark to dark bluish grey in colour, fine grained, with occasional zeolite filled cavities. The zeolites were identified as of okenite and heulandite varieties.

2.4. Sub-surface Geology

The details of the sub-surface geological conditions in the area were obtained by drilling a series of bore holes in a grid pattern and drawing a cross section through them (Fig.4). A true picture of a wider area was obtained by trench and pit excavations. Fig.5 shows the actual details of various formations present underground. These formations were exposed on the western wall of a pit (18' x 13'-6") made near decontamination facility now back filled.

At the time of levelling the area, a lot of back-filling was done with the result natural sequence of sub-surface formations has been disturbed at a number of places. However, the overall sub-surface conditions are consisting of an over-burden of 1 to 2 metres thickness, composed of clayey soil, decayed vegetation and small pebbles of weathered basalt. This zone of over-burden is followed by a highly weathered formation to a depth of 8 - 9 metres. The weathered rock when dry, crumbles easily to a powdery mass. Core recovery was poor during the drilling operations. Fine-grained yellowish-brown to dark brown sludge was recovered which on examination indicated the presence of highly weathered zone of basalt rock. Undisturbed samples from these horizons were collected and were examined megascopically and microscopically confirming
the presence of the above rock formation. The rock is fine grained, hard, compact and bluish grey colour, with occasional amygdaloidal structure having zeolites, secondary calcite and silica in them. The basalt shows two sets of lateral joints and at places vertical cracks along which it breaks easily.

2.5. Hydrology

Warm, humid climate prevails throughout the year with a maximum humidity of 90 - 95% during the rainy season from June to September and a minimum humidity of 30 - 40% for the rest of the year. The annual rainfall is heavy and is recorded as between 1900 to 2600 mm; in a single day it may rain as much as 100 to 150 mm at a stretch. This peculiar rainfall pattern influences the erosion of the soil, surface and sub-surface water conditions. Depending upon the rainfall conditions and temperature prevalent, it was observed that total run-off varies between 50 - 75% of the precipitation in the area (1) and only 25 - 50% of the precipitation infiltrates to the ground.

Because of the limited thickness of the permeable strata, the percolated water is generally confined to the weathered basalt formation and soil over-burden. The underlying fresh basalt is practically impervious and only little water may seep through cracks and joints, if present. The water table rises considerably during the rainy season almost upto 0.5 metre from the surface. During the peak drought months, the water table recedes to the level of 9 - 10 metres depending upon the position of impervious strata down below. The hydrographs give an idea of fluctuations in water levels during the year (Fig.6).

3. GROUND WATER MOVEMENT STUDIES

3.1. General Considerations

It is observed from the sub-surface geological conditions that:

(i) The soil capping is not uniform and of graded material.
(ii) The intensity of weathering of basalt varies considerably.
(iii) The original joint pattern and cracks have been changed considerably due to the weathering. These conditions vary from place to place and in addition to them, peculiar climatic conditions prevalent have a direct control over the movement of ground water in the area. Depending upon the field conditions various field experiments were
conducted.

3.2. Tracer Studies

Ground water movement studies were carried out by injecting suitable tracer dye in a centrally located well and tracking its movement in the surrounding wells. These experiments indicated the direction and rate of movement of ground water in that particular zone. The results of these experiments are given in Table I to IV.

The above studies were carried out in selected bore holes located in zone-A, 1, 2, 3 and 4 covering approximately eastern-half-area of the Site.

4. DISCUSSION

From the above studies it was observed that the general direction of ground water movement is towards south leading to bay with a velocity varying from 0.8 to 1.2 ft/day. However, a secondary ground water movement was also observed along the joint patterns of the rocks in east-west direction with a velocity varying from 0.9 to 5.6 ft/day.

5. CONCLUSIONS

The experiments indicate that the movement of radioactivity in an accidental release from the contained facility of the storage site is likely to move towards the Trombay bay. As the average velocity of ground water is very slow, it will provide an additional time factor for the active ions to reach to the bay.

ACKNOWLEDGEMENTS

The authors express their sincere gratitude to Shri K.T. Thomas, Head, Waste Treatment Division, Shri R.V. Amalraj and Shri A.A. Khan for their valuable suggestions and according all the necessary facilities in carrying out these studies.

REFERENCES

### Table 1

**Ground Water Movement Studies at Bass - Trombay**

<table>
<thead>
<tr>
<th>No.</th>
<th>Location of the Bore Well</th>
<th>Nature of the sub-surface strata</th>
<th>Water level at the time of injection of tracer</th>
<th>Date and time of injection of tracer</th>
<th>Date and time of tracer detection in the surrounding bore well and depth of water level</th>
<th>Time and direction of the movement of tracer</th>
<th>Ground water velocity</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>B.H. B3A - 6&quot; diameter located to the east of Zone A near Bass Boundary.</td>
<td>0'-0&quot; - 3'-0&quot; over burden and soil.</td>
<td>31'-0&quot; - 61'-0&quot; weathered basalt rock.</td>
<td>151/2' Rhodamine-B dye dissolved in ground water and injected in the bore well on 30.4.69 at 17 hrs.</td>
<td>i) Tracer detected in B.H. B3A-IV on 1.5.69 at 7 AM at 15'12&quot; depth. ii) Tracer detected in B.H. B3A-I on 1.5.69 at 15 hrs. at 15'12&quot;. iii) Tracer detected in B.H. B3A-III on 1.5.69 at 14 hrs at 15'12&quot;.</td>
<td>After 14 hrs in the Southern direction. After 21 hrs in the western direction. After 21 hrs in the eastern direction.</td>
<td>8.4 ft/day</td>
<td>distance between the central well &amp; surrounding well is 5 ft. general direction of flow of water is towards the north leading into the bay, while the east west flow is along the joint planes. The high rate of velocity of water appears to be due to the presence of a fissure at that horizon.</td>
</tr>
<tr>
<td>2</td>
<td>Experiment repeated</td>
<td>-do-</td>
<td>18'0&quot; Rhodamine-B dye dissolved in ground water &amp; injected in the bore well on 8.5.69 at 18 hrs.</td>
<td>1) Tracer detected in B.H. B3A-IV at 8 hrs. on 7.5.69. at 18'-0&quot; depth. 11) Tracer detected in B.H. B3A-I on 7.5.69 at 14.30 hrs. at 18'10&quot;. 111) Tracer detected in B.H. B3A-III on 7.5.69 at 18 hrs at 18'10&quot;.</td>
<td>After 14 hrs in southern direction. After 20 hrs in 50 min. in the western direction. After 21 hrs in the eastern direction.</td>
<td>6.1 ft/day</td>
<td>5.5 ft/day</td>
<td>5.4 ft/day</td>
</tr>
<tr>
<td>3</td>
<td>Experiment repeated</td>
<td>-do-</td>
<td>18'7&quot; Rhodamine-B dye dissolved in ground water and injected in the bore well on 14.5.69 at 18 hrs.</td>
<td>Tracer detected in B.H. B3A-IV on 15.5.69 at 7 hrs at 18'10&quot; depth.</td>
<td>After 15 hrs in the southern direction.</td>
<td>5.5 ft/day</td>
<td>5.5 ft/day</td>
<td>5.5 ft/day</td>
</tr>
<tr>
<td>No.</td>
<td>Location of the Bore Well</td>
<td>Nature of the Sub-surface strata</td>
<td>Water level at the time of injection of tracer dye from ground level</td>
<td>Date and time of injection of tracer and position of the injection well</td>
<td>Date and time of tracer detection, bore level and depth of tracer</td>
<td>Time and direction of the movement of tracer</td>
<td>Ground water Remarks</td>
<td>Remarks of the movement velocity</td>
</tr>
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</tr>
<tr>
<td>1.</td>
<td>C5A-6' diameter and 36' deep-located in a corner of the decontamination facility area and N.W. of Zone A. Distances between C5A and the surrounding wells are 21'-8&quot; respectively</td>
<td>0'-0' - 21'-8&quot; Over burden and soil 21'-8&quot; - 68'-6&quot; Weathered basalt 68'-6&quot; - 86'-0&quot; Fresh hard and compact basalt bluish grey in colour with Zeolite filled cavities at places</td>
<td>Rhodamine-B dye dissolved in ground water and injected in the bore well on 25.4.69 at 14 hrs.</td>
<td>C5A III; 5' dia. bore well 41'-4&quot; west of the central well on 25.4.69 at 14 hrs.</td>
<td>67 hrs. 50 minutes 0.8 ft/day</td>
<td>0.68 ft/day</td>
<td>0.62 ft/day</td>
<td>0.84 ft/day</td>
</tr>
<tr>
<td>2.</td>
<td>Experimental repeated</td>
<td>- do -</td>
<td>Rhodamine B dye solution injected in bore well No. C5A on 8.5.69 at 17 hrs.</td>
<td>C5A IV at 14 hrs. of 6.5.69 at 12' 7&quot; depth</td>
<td>52 hrs. south of central wall</td>
<td>1.15 ft/day</td>
<td>General direction of ground water flow is towards south leading into the bay while the east west flow to some extent is along the joint planes</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Experimental repeated</td>
<td>- do -</td>
<td>Rhodamine B dye solution injected in bore well C5A on 12.5.69 at 10 hrs.</td>
<td>C5A III at 10hrs. on 15.5.69 at 18' 8&quot; depth</td>
<td>72 hrs. west of the central wall</td>
<td>0.85 ft/day</td>
<td>0.82 ft/day</td>
<td>0.62 ft/day</td>
</tr>
</tbody>
</table>
## TABLE - III

**GROUND WATER MOVEMENT STUDIES AT BASS - TROMBA**

<table>
<thead>
<tr>
<th>No.</th>
<th>Location of the Bore Well</th>
<th>Nature of the Sub-surface strata</th>
<th>Water level at the time of injection of the tracer dye from ground level</th>
<th>Date and time of tracer detection in the surrounding bore well and depth of water level</th>
<th>Time and direction of the movement of water tracer</th>
<th>Ground Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>B.H.Bg - 6&quot; diameter, located in Zone-2.</td>
<td>0'-0&quot; - 9'-0&quot; over burden of soil and assorted material used for reclaiming the area.</td>
<td>9'-0&quot; - 7'-0&quot; weathered basalt.</td>
<td>13'-4&quot; Rhodamine-B dye dissolved in ground water and injected in the bore well on 16.10.69 at 15 hra.</td>
<td>After 253 hours in the southern, east direction.</td>
<td>1.00 ft/day</td>
</tr>
<tr>
<td>2.</td>
<td>Experiment repeated</td>
<td>22'-0&quot;-41'-0&quot; Hard and compact basalt with occasional Zeolite-filled cavities.</td>
<td>Bore hole was closed at 41'-0&quot; depth.</td>
<td>13'-4&quot; Rhodamine-B dye dissolved in B.H.-Bg IV at 9 AM on 27.10.69 at 15'-41&quot; depth.</td>
<td>In 257 hours in the western direction well.</td>
<td>0.93 ft/day</td>
</tr>
</tbody>
</table>

Distances between the central well Bg-4, surrounding wells III, IV, V & VI are 10ft and that between I & II are 5ft.

The area around has been partly reclaimed while levelling by soil etc. brought from outside.
<table>
<thead>
<tr>
<th>No.</th>
<th>Location of the Bore Well</th>
<th>Nature of the Sub-surface strata</th>
<th>Water level</th>
<th>Date and time of injection of the tracer and position of the dye from the injection well</th>
<th>Date and time of tracer detection in the surrounding bore well and depth of water level</th>
<th>Time and direction of tracer movement</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>E.H.B.-I - 6&quot; diameter located in Zone I</td>
<td>8.1'-O'- 5.5'-O' Highly weathered basalt, water over flow of yellow colour.</td>
<td>5'-O'- 5.5'-O' Weathered basalt</td>
<td>2'-O' Rhodamine-B dye was dissolved in ground water and was injected in the bore well on 15.10.69 at 16 hrs.</td>
<td>16.10.69 at 16 hrs at 5'-O' depth.</td>
<td>1.5 ft/day in the western direction.</td>
<td>Dye was detected in E.H.B.-I after 67 hours.</td>
</tr>
<tr>
<td>2.</td>
<td>-do-</td>
<td>-do-</td>
<td>7.1'-O' Weathered basalt, water over flow of yellow colour.</td>
<td>7.1'-O' Weathered basalt, water over flow of yellow colour.</td>
<td>16.10.69 at 9 AM at 7.1'-O' depth.</td>
<td>1.2 ft/day in the Southern direction.</td>
<td>Dye was detected in E.H.B.-I after 63 hours.</td>
</tr>
<tr>
<td>3.</td>
<td>Experiment repeated</td>
<td>-do-</td>
<td>9.7'-O' Weathered basalt, water over flow of yellow colour.</td>
<td>9.7'-O' Weathered basalt, water over flow of yellow colour.</td>
<td>16.10.69 at 10 AM at 9.7'-O' depth.</td>
<td>1.2 ft/day towards east and 80' E.</td>
<td>Dye was detected in E.H.B.-I after 64 hours.</td>
</tr>
</tbody>
</table>
TOPO-GRAPHICAL MAP OF THE RADIO-ACTIVE STORAGE SITE-TROMBAY B.A.R.C
(BEFORE LEVELING)
- BORE HOLES DRILLED WITH SPOT LEVELS
RADIO-ACTIVE STORAGE SITE-TROMBAY
LAY OUT
WITH REVISED BORE HOLE LOCATIONS

NOTE:
1. SOME HOLES NOW EXISTING ON ROAD ARE OUT OF GRID PATTERN HERE DRILLED AS PER OLD GRID PATTERN BEFORE LAY OUT OF THE SITE WAS PREPARED.
2. SOME OF THE BORE HOLES HAVE BEEN SIMPLY OMITTED OUT THE NEW GRID PATTERN FOR THE DRILLING CONVENIENCE.
3. SERIAL NUMBERS FOR BORE HOLE LOCATIONS IN NEW GRID PATTERN FALLING ON BUILDINGS, ETC. OUT OF SCALE DUE TO UNFORTUNATE.
4. PROPOSED BORE HOLES, BUT DRILLED BORE HOLES. THIS DRAWING IS TRACED FROM A BORE HOLE E.E.F. DRAWING NO E.E.F. 5-3-24.

V.H. GODDE
W.T.D., B.A.R.C.

FIG. 2.
GEological Map of Trombay Island

Legend:
- Trombay Establishment
- Alluvium
- Granophyre
- Basic Tuff
- Basalt
- Dolerite Dykes
- Okeanite & Ankarapite
- Dip 7°-12°

FIG. 3.
GEOLOGICAL SECTION PASSING THROUGH BORE-HOLES NO. B8, B7, B6, B5, B3, B2, B1A, B1 AT RASS.
FIG. 5.

1. SOIL WITH HUMUS
2. YELLOWISH BROWN SOIL WITH PEBBLES
3. DARK COLOURED SOIL WITHOUT PEBBLES
4. HIGHLY WEATHERED BASALT ROCK—YELLOWISH IN COLOUR
5. WEATHERED BASALT—YELLOWISH BROWN IN COLOUR WITH CRACKS & JOINTS
HYDROGRAPHS AND RAIN FALL DATA FOR TROMBAY SITE

RAIN FALL DATA FOR THE TROMBAY SITE

GROUND SURFACE

BORE HOLE E-S

BORE HOLE C-1

BORE HOLE C-5

BORE HOLE C-6

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FIG. 6.