

Single Air passage results (10 membrane scrub):

Fine Dust Particles **99.9%** elimination
 Coarse Dust Particles **99.9%** elimination
 Bacterial microbes **99.9%** elimination

5 x cycles (130 membrane scrub):

	elimination	pre-test	post-test	Reduction
Hexane	38.37%	1825.6 ppm	1125 ppm	-700.6 ppm
Acetone	98.75%	2941.2 ppm	36.6 ppm	-2904.6 ppm

24 x Cycle (600 membrane Scrub):

Sulphur dioxide (SO₂) **58%** elimination
 Carbon monoxide (CO) **76%** elimination
 Oxygen (O₂) **0.5%** increase
 Nitrogen dioxide (NO₂) **91%** elimination

(600 membrane) Result Break Down:

	Start	< number of membranes >							
	30	80	130	250	330	500	600		
% SO₂	17.7	17.5	16.7	15.6	13.1	10.7	8.6	7.3	
Reduction		0.2	0.8	1.1	2.5	2.4	2.1	1.3	
% Reduction		-1.1	-4.57	-6.58	-16	-18.3	-20	-15	
PPM CO	696	586	528	483	363	276	210	167	
Reduction		110	58	45	120	87	66	43	
% Reduction		-15	-9.8	-8.5	-24	-23.9	-23.9	-20.4	
% O₂	20.4	20.6	20.6	20.7	20.8	20.9	20.9	20.9	
PPM NO₂	4.8	4.1	2.4	1.9	1.2	0.9	0.6	0.4	
Reduction		0.7	1.7	0.5	0.7	0.3	0.3	0.2	
% Reduction		-14.5	-41	-20	-36	-25	-33	-33	

Please Note: The Outdoor **AP²K** system is equipped with over **3000** membranes



ENVIRONMENTAL SCIENCE

SERVICES CONSULTANTS

(Pty) Ltd./ (Edms) Bpk
Reg. no. 89/07432/07

10606/Wb/gr

7 June 2000

**GENESIS RESEARCH
P O BOX 472
ROSETTENVILLE
2130**

ATT: MR. SHAWN STEWART

Dear Sir,

REPORT ON SCRUBBER EVALUATIONS


Enclosed herewith is our report detailing results obtained from the abovementioned survey.

We trust the information contained in this report fulfils the requirements as specified. Should you, however, require additional information or clarification of any matter, please do not hesitate to contact us.

Also enclosed is our invoice. Payment would be appreciated within 30 days of date thereon.

We thank you for the opportunity of being of assistance to your company, and assure you of our continued best services at all times.

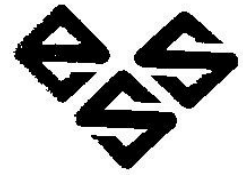
Yours sincerely,


WILLEM BARWISE

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7 June 2000

**GENESIS RESEARCH
P O BOX 472
ROSETTENVILLE
2130**

ATT: MR SHAWN STEWART

Dear Sir,

REPORT ON SCRUBBER EVALUATIONS

1. OBJECTIVE OF THE PROJECT:

The objective of the project was to evaluate the performance of a pilot plant scrubber in removing air pollutants from the air.

2. METHODOLOGY:

It was mutually decided to challenge the unit with the following pollutants:

- Inorganic gases : CO, CO₂, O₂, NO₂, SO₂ and H₂S.
- Organic vapours : Formaldehyde, hexane and acetone.
- Particulate matter : Dust of varying particle size, tobacco smoke.
- Micro-organisms

2.1 Generation of pollutants:

2.1.1 Inorganic gases:

Nitrogen dioxide was generated artificially by boiling concentrated HNO₃ on a hot plate close to the inlet of the

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unit. All other gases were generated by venting air via a pipe from the exhaust of a petrol engine to the inlet of the unit.

2.1.2 Organic vapours:

Hexane, acetone and formaldehyde vapours were generated by heating the relevant solutions to evaporation point close to the inlet of the unit.

2.1.3 Dust and smoke:

Dust was emitted into the inlet of the unit by shaking the filter of a household vacuum cleaner at the units' inlet. Smoke was generated by burning a cigarette from which smoke was blown into the inlet of the unit.

2.1.4 Micro-organisms were introduced into the unit by passing severely contaminated (toilet) water, through a spray (mist) generator into the unit.

2.2 Measurement of air pollutant concentrations:

2.2.1 Inorganic gases:

Inorganic gas concentrations were determined by means of on-line gas analysers (Oldham MX21). Relevant concentrations were either recorded or read off and logged manually at specific time intervals. Inorganic gases were measured with the unit operating in a closed loop (100% recirculation), after introduction of the gases. The concentrations were recorded in a fixed position in the inlet duct of the unit.

3. RESULTS:

3.1 Inorganic gases:

Analysis results for the individual gases evaluated are as follows:

Elapsed time (Min.)	Concentrations of gases	
	NO ₂	% Decrease
11h49 - 0; Start of test / no scrubbing	5,1	-
11h55 - 6; Water sprays switched on	4,8	5,9
1	4,1	14,6
2	2,8	31,7
3	2,4	14,3
4	2,1	12,5
5	1,9	9,5
6	1,7	10,5
8	1,4	17,6
9	1,3	7,1
10	1,2	7,7
11	1,2	0
12	1,1	8,3
13	1,0	9,1
14	0,9	10,0
15	0,9	0
16	0,8	11,1
20	0,6	25
24	0,4	33,3

Elapsed time (Min)	O ₂ %	% R/I	CO ppm	% R	NO ₂ * ¹ ppm	% R	SO ₂ ppm	% R	CO ₂ %* ²	% R
0; Fan on; scrubber off	20,4		696		0,2	N/A	17,7		0,5	N/A
12h10 - 1; Scrubber on	20,6	+0,2	586	15,8	0,2	N/A	17,5	1,1	0,4	N/A
3	20,6	0	528	9,9	0,2	N/A	16,7	4,6	0,4	N/A
5	20,7	+0,1	483	8,5	0,2	N/A	15,7	5,9	0,4	N/A
10	20,8	+0,1	363	24,8	0,2	N/A	13,1	16,6	0,4	N/A
15	20,9	+0,1	276	23,7	0,2	N/A	10,7	18,3	0,4	N/A
20	20,9	0	210	23,9	0,1	N/A	8,6	19,6	0,4	N/A
24	20,9	0	167	20,4	0,1	N/A	7,3	15,1	0,4	N/A

Note: Also see graphs for NO₂, CO and SO₂ attached.

*¹ = NO₂ concentrations at instruments lower detection limit. (Immeasurable - repeated as reflected in Table above).

*² = Instrument sensor appears to be faulty (can only replace in 3-6 weeks' time).

% R = % Reduction

% R/I = % Reduction or increase (+)

3.2 Organic vapours:

Organic vapour analysis results are as follows:

Description / condition	Formaldehyde	Hexane	% Reduction	Acetone	% Reduction
Test 1; No scrubbing (for 5 min)	BDL	1825,60	-	2941,20	-
Test 2; Scrubber on for 5 minutes	BDL	1125,0	38,4	36,6	98,8

Samples were taken over 5-minute periods each.

BDL = Below Detection Limit (10µg)

3.3 Dust and smoke:

The combination of dust and smoke concentrations measured in the scrubber inlet and outlet ducts respectively over a period of 25 minutes were as follows:

- **Scrubber inlet** : Very high (accurate concentrations could not be measured due to the high dust loading applied).
- **Scrubber outlet** : No dust could be detected on the filters.

Note: Although no dust could be detected on the outlet, tobacco smoke could still be detected by smell after approximately 5 minutes of scrubbing.

3.4 Microbes:

The test results of the three sets of tests were as follows:

Condition	Result and position	
	Inlet	Outlet
Low loading	High growth	No cfu's
Medium loading	Very high growth	No cfu's
Very high loading	Totally overgrown	No cfu's

cfu's = colony forming units

Note: Conclusions are based on the results obtained for the conditions evaluated and for the relevant test periods only.

4. **DISCUSSION OF RESULTS AND CONCLUSIONS:**

From the results obtained, the following could be concluded:

4.1 **Inorganic gases:**

4.1.1 **Nitrogen dioxide:**

NO₂ concentrations indicate a reduction from 5,1ppm to 0,4ppm, in approximately 24 minutes (92,2%). What is not clear, is why a 6% reduction took place when the scrubber was not operational. The lower detection limit of the MX21 for NO₂ is 0,2ppm.

4.1.2 **Oxygen:**

Oxygen concentrations showed a slight increase in concentration (0,5%), over the sampling period from 20,4 to 20,9% (20,9% is the normal background concentration for O₂), over a period of 24 minutes. Exhaust gases contain low O₂ concentrations which will explain the initial concentration of 20,4%.

4.1.3 **Carbon monoxide:**

CO levels reduced from a high of 696 ppm to 167 ppm in 24 minutes (76% reduction). Exhaust gases contain high CO levels, explaining the start concentrations of 696 ppm.

4.1.4 **Sulphur dioxide:**

SO₂ concentration dropped from 17,7 ppm to 7,3 ppm in 24 minutes (58%). Exhaust gases contain high SO₂ concentrations explaining the elevated start concentrations.

4.1.5 **Carbon dioxide:**

CO₂ levels could not be determined accurately due to a faulty sensor.

4.2 **Organic vapours:**

The scrubber appears to be effective in the removal of organic vapours from the air. For acetone, the reduction in concentrations was very good at 98,8%, but for N-hexane, a reduction of only 38% was achieved.

4.3 **Dust and smoke:**

Dust:

The effectiveness of the scrubber appears to be excellent in the removal of dust particles from the air. From the results obtained, it could be concluded that a more than 99% removal of dust was obtained as could be expected of any well-designed scrubber or bag filtration system.

Smoke:

The effectiveness of the removal of tobacco smoke from the air is questionable, as smoke generated at the inlet could be detected by smell at the outlet after approximately five minutes of scrubbing. This could be due to the fact that smoke particles are very small and thus pass through the scrubber and filters.

4.4 **Microbes:**

A 100% efficiency of microbe removal was demonstrated. This could be due to the fact that the microbes were in a water

suspension and although applied as a mist, will be readily removed by the scrubber water curtain, mist eliminator and filter.

5. **GENERAL OPERATING CONDITIONS:**

The various operating conditions that prevailed and that were evaluated during the "closed system" evaluations are as follows:

Ambient and thus scrubber inlet:

- RH : 12-14%
- O₂ : 20,9%

In system with scrubber on:

- RH : 74%
- O₂ : 20,9% (No change in O₂ content)

Air velocity:

- 3,5m/s without filters
- 1,7m/s with filters (51,4% reduction)

RH:

- 17-20% (filters in; humidifier on; scrubber off)
- 82% (scrubber and humidifier on)

The increase in RH is a concern, as in any environment, an increase in RH above optimum (40-60%), will result in a marked sense of discomfort.

6. **GENERAL:**


Extrapolations based on the data on hand will not be made by E.S.S.C., due to the many uncertainties attached to scrubber setup, which could have contributed to reductions and increases in gas and vapour

concentrations e.g. potential or probable leakages into the system for which we do not have 100% proof. Should you wish to do your own extrapolation, please feel free to do so. The removal efficiency of dust and droplets containing microbes would, in all probability, have been achieved even when water without additives was used followed by filtration.

In my opinion, should you wish to test your concept and prove that it is in fact, working as expected, a laboratory scale project that will rule out all uncertainties surrounding the present project, should be embarked upon. Based on the preliminary test results obtained, we are, however, of the opinion that it was demonstrated that reductions in pollutant levels were achieved by the pilot unit.

Should any further assistance or information be required, please do not hesitate to contact us.

Yours sincerely,



WILLEM BARWISE