



Ricerca di Sistema elettrico

Caratterizzazione composizionale del syngas proveniente dalla gassificazione di carbone e biomasse

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CARATTERIZZAZIONE COMPOSIZIONALE DEL SYNGAS PROVENIENTE DALLA GASSIFICAZIONE DI CARBONE E BIOMASSE

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Progetto: Cattura e sequestro della CO₂ prodotta dall'utilizzo di combustibili fossili

Obiettivo: Tecnologie innovative per la cattura della CO₂ in pre-combustione, Post-Combustione e produzione di combustibili gassosi

Responsabile del Progetto: F. R. Picchia ENEA

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Sommario

Sono state effettuate 4 campagne di campionamento del syngas proveniente dall'impianto pilota di gassificazione della SOTACARBO. I campionamenti sono stati eseguiti secondo una procedura messa a punto, in termini di scelta delle prese e delle modalità di prelievo, per la raccolta di campioni finalizzata all'analisi della composizione del syngas relativamente ai macrocostituenti (H_2 , CH_4 , CO , CO_2 , N_2 , O_2 , H_2O), ai contaminanti principali (H_2S , COS , HCl , HF , NH_3) e al TAR. I risultati ottenuti indicano che le procedure utilizzate sono appropriate per il raggiungimento degli obiettivi prefissati, anche se esistono dei margini di miglioramento, soprattutto per quanto riguarda l'individuazione di ulteriori punti di prelievo.

1 Introduzione

Nel syngas prodotto dalla gassificazione sono presenti, indipendentemente dalla alimentazione utilizzata, sottoprodotti indesiderati, quali polveri e contaminanti in quantità più o meno rilevanti. Tali componenti possono avere effetti dannosi sia sull'impianto (tubazioni, valvole, filtri, etc.) che sugli utilizzatori finali (bruciatori, motori a combustione interna, turbine, reattori catalitici, etc.), ma anche sull'ambiente, qualora fossero rilasciati in atmosfera. Le quantità relative dei diversi componenti inquinanti, oltre che dal tipo di gassificatore, dipendono dalle condizioni di gassificazione e dal tipo di carica impiegata. Il particolato (grossolano o fine) e il catrame possono essere causa di erosione, corrosione e occlusioni in seguito alla loro deposizione in parti dell'impianto a valle del reattore di gassificazione, ma possono anche essere causa di inquinamento ambientale, in seguito all'emissione di sostanze nocive e contaminazione di eventuali sorbenti e/o catalizzatori. Altri contaminanti nocivi possono essere composti alogenati a base di cloro e fluoro, composti dello zolfo e dell'azoto, nonché metalli pesanti. Da quanto detto emerge chiaramente che la determinazione della composizione del syngas, con particolare riferimento alla concentrazione e alla natura dei contaminanti principali, è di fondamentale importanza per un corretto funzionamento degli impianti.

In questo lavoro sono riportati i risultati delle analisi composizionali del syngas, relativamente ai macrocostituenti (H_2 , CH_4 , CO , CO_2 , N_2 , O_2 , H_2O) e ai contaminanti principali, quali H_2S , COS , HCl , HF , NH_3 , particolato e TAR.

2 Descrizione delle attività svolte e risultati

2.1 Descrizione delle modalità di campionamento

Sono stati effettuati quattro campionamenti in concomitanza con la marcia dell'impianto in data :

19 maggio 2016 (alimentazione biomassa)

05 luglio 2016 (alimentazione 90% carbone colombiano + 10% biomassa)

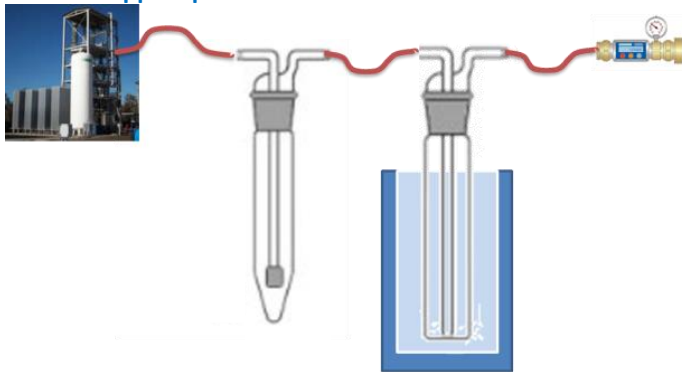
27 luglio 2016 (alimentazione biomassa)

07 settembre 2016 (alimentazione carbone colombiano).

I campionamenti sono stati effettuati nel secondo o nel terzo giorno di marcia, in modo da operare sull'impianto dopo il raggiungimento delle condizioni stazionarie.

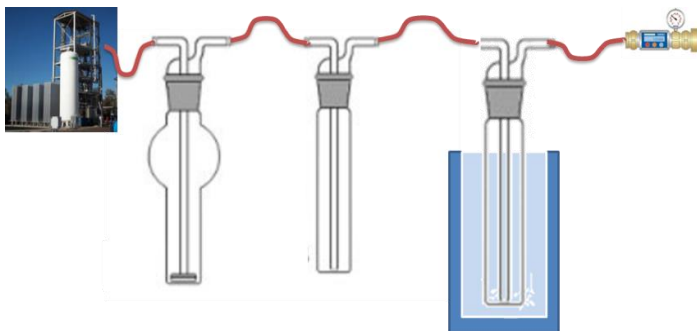
Per quanto riguarda il TAR, i campionamenti sono stati effettuati subito dopo l'uscita del gassificatore, mediante una linea di prelievo con un passo dei tubi da 1/4" riscaldata a 200 °C. Il TAR è stato raccolto per gorgogliamento dell'effluente dal gassificatore in tre bottiglie di raccolta di tipo Drechsel, poste in serie e immerse in una trappola con ghiaccio (Schema 1), e contenenti isopropanolo (C_4H_8O) che, come è noto, è considerato il solvente più adatto [1]. Oltre che per favorire la condensazione del TAR, la trappola con ghiaccio è necessaria all'eliminazione dell'umidità prima che il gas arrivi al totalizzatore di portata, mediante il quale è possibile determinare la quantità di gas che fluisce nelle trappole durante il tempo di campionamento.

Schema 1. Trappole per TAR

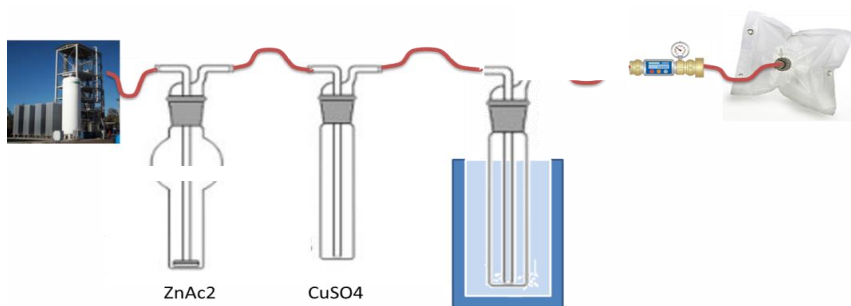


Per la determinazione degli altri contaminanti principali, il punto di campionamento si trova a circa due metri dall'uscita del gassificatore; la linea di prelievo è costituita da un tubo di gomma non riscaldato collegato da una parte ad un'uscita per tubi da 1/8", munita di una valvola a spillo per la regolazione della portata gassosa, e dall'altra all'ingresso del sistema di trappole di raccolta (Schemi 2 e 3). Anche in questo caso è presente una trappola con ghiaccio prima dell'ingresso del gas al totalizzatore di portata.

Schema 2. Trappole per acidità totale e ammoniacca



Schema 3. Trappole per solfuri e per la determinazione dell'umidità



Le soluzioni contenute nelle Drechsel di raccolta sono le seguenti:

- 1A, contenente NaOH a titolo noto, per la determinazione dell'acidità totale e degli alogenuri,
- 1B, contenente H₂SO₄ a titolo noto, per la determinazione del contenuto di ammoniaca (misurato come ione ammonio),
- 2A, contenente Zn(CH₃COO)₂, per la determinazione dei solfuri (misurati come ZnS),
- 2B, contenente una soluzione di CuSO₄ a titolo noto, per la determinazione del contenuto di umidità.

Il syngas per la determinazione dei macrocostituenti (H₂, CH₄, CO, CO₂, N₂, O₂) viene raccolto collegando l'uscita della linea di prelievo a freddo usata per i contaminanti principali, ad una apposita sacca, previa eliminazione dell'umidità per condensazione in una trappola con ghiaccio.

Le soluzioni ed il gas prelevato sono stati in seguito analizzati nei laboratori del dipartimento con le metodiche riportate di seguito.

2.2 Metodiche di analisi

2.2.1. Analisi dei contaminanti

- Ammonio: 1mL di campione prelevato dalla Drechsel 1A è stato diluito a 50 mL con acqua distillata. La soluzione è stata titolata volumetricamente con HCl a titolo noto. La misura è stata ripetuta 3 volte.
- Acidità totale: 1mL di campione prelevato dalla Drechsel 1B è stato diluito a 50 mL con acqua distillata. La soluzione è stata titolata volumetricamente con NaOH a titolo noto. La misura è stata ripetuta 3 volte.
- Solfuri: I solfuri sono stati precipitati nella Drechsel 2A per reazione con acetato di zinco in ambiente tamponato per acido acetico. La soluzione contenente ZnS solido è stata filtrata sotto vuoto. Il prodotto solido è stato lavato con acqua distillata, essiccato e pesato.
- Alogenuri: 10 mL di soluzione prelevata dalla Drechsel 1A sono stati neutralizzati con H₂SO₄. La determinazione, quando necessaria, è stata fatta per titolazione con AgNO₃ a titolo noto e K₂CrO₄ come indicatore.

2.2.2. Analisi dei macrocostituenti

Il gas raccolto nelle sacche di prelievo è stato analizzato con un gascromatografo Agilent mod. 6890N (Figura 1), equipaggiato con un iniettore split/splitless, un rivelatore TCD ed un metanatore collegato al rivelatore FID. Il gas è stato iniettato mediante una valvola di campionamento a 6 vie. Le analisi sono state nelle seguenti condizioni sperimentali:

- colonna HP Plot Q, 30 m di lunghezza, diametro interno 530 µm; spessore del film 40 µm
- gas carrier, He o N₂ (5 ml/min); modalità constant flow
- rapporto di splittaggio, 15
- T iniettore, 180 °C
- T rivelatori (TCD e FID), 250 °C
- T metanatore, 360 °C
- programmata di temperatura: -40 °C per 3 min, 30 °C/min fino a 200 °C per 7 min.



Figura 1. Strumentazione utilizzata per l'analisi del syngas.

L'analisi quantitativa è stata effettuata mediante calibrazione con 3 miscele standard, fornite dalla SAPIO, utilizzando il metodo dello standard esterno. La determinazione dei componenti con più di tre atomi di carbonio (definiti come C3+), non presenti nelle miscele di calibrazione, è stata effettuata utilizzando il fattore di correzione del propano. H₂S e COS sono stati calibrati con una sola miscela in N₂ al 2 % in volume.

Il contenuto di umidità è stato invece determinato mediante gorgogliamento in una soluzione a titolo noto di CuSO₄. Il titolo dello ione Cu(II) è stato determinato attraverso titolazione spettrofotometrica (Figura 2). La percentuale di umidità è stata calcolata sulla base della differenza di concentrazione del Cu(II).



Figura 2. Spettrofotometro UV-Vis Varian Cary 60.

2.2.3. Analisi del TAR

L'analisi per il riconoscimento dei componenti del TAR è stata effettuata utilizzando una Gas-Massa quadrupolare (mod. 5975, Agilent Technologies) accoppiata con un gascromatografo mod. 7820A (Figura 3).

Le condizioni sperimentali adottate sono le seguenti:

- Colonna ZB-5 della Phenomenex, lunghezza 30 metri, diametro interno 0.25 mm, spessore film 0.25 μm .
- Programmata di temperatura : T iniziale = 40 °C, per 5 minuti; riscaldamento 40°C/minuto fino alla temperatura finale di 250 °C, per 20 minuti.
- T di iniezione = 230 °C.
- T transfer-line = 280 °C.
- T sorgente = 230 °C.
- T quadrupolo = 150 °C.

Per evitare interferenze da parte del solvente, lo strumento ha iniziato ad acquisire i dati dopo 2 minuti dall'iniezione del campione. Prove preliminari hanno permesso di determinare che il tempo di solvent delay scelto (2 minuti) non preclude l'acquisizione del segnale dovuto alle specie più leggere che vengono considerate componenti del TAR.

Il contenuto delle 3 Drechsel di raccolta del TAR è stato miscelato, filtrato e analizzato alla Gas-Massa per determinare la natura dei componenti del TAR. Quando presente, il solido residuo rimasto sul filtro, insolubile in isopropanolo, è stato essiccato e pesato. Una porzione del filtrato è stata poi prelevata ed evaporata in evaporatore rotante alla temperatura di 80 °C. Dopo eliminazione del solvente, il solido è stato essiccato in stufa a 50°C per una notte, pesato, e infine ripreso con 10 ml di isopropanolo e di nuovo analizzato alla Gas-Massa. La procedura è riassunta in Figura 4 per il campione raccolto durante la campagna del 05 luglio 2016.



Figura 3. Strumentazione GC-MS.



Figura 4. Procedura di preparazione del campione per l'analisi del TAR: (a), campione in isopropanolo; (b), filtrazione; (c), prelievo del filtrato; (d) evaporazione del solvente; (e) campione dopo evaporazione.

2.3 Reperti fotografici

Le Figure seguenti riportano alcune foto relative all'allestimento delle trappole e prelievo dei campioni delle diverse campagne di campionamento.

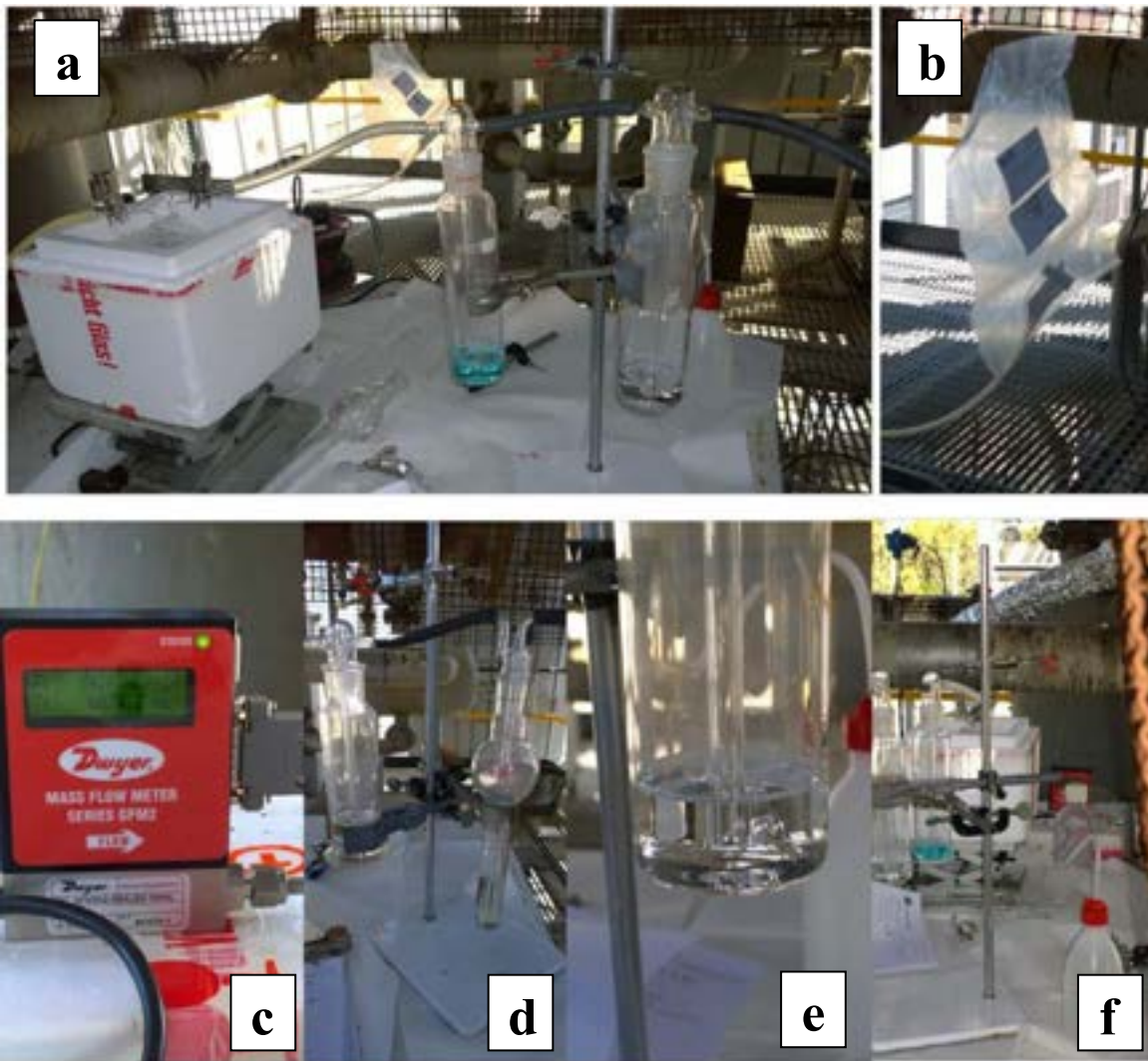


Figura 5. Allestimento delle trappole e prelievo dei campioni relativi alla campagna del 19 maggio 2016: a. particolare delle trappole per solfuri e umidità; b. sacca di raccolta del gas; c. totalizzatore di portata; d. Drechsel per la misura dell'acidità totale; e. soluzione di NaOH, incolore anche dopo passaggio del gas; f. vista della zona di campionamento.



Figura 6. Allestimento delle trappole e prelievo dei campioni relativi alla campagna del 05 luglio 2016: a. particolare delle trappole per solfuri e umidità; b. Drechsel per la raccolta del tar; c. camicia termostatica per il prelievo del tar; d. vista della zona di campionamento; e. Trappola con ghiaccio per la condensazione dell'umidità prima dell'ingresso al totalizzatore di portata; f. raccolta del tar e misura del flusso; g. valvola a spillo per la regolazione della portata del gas.

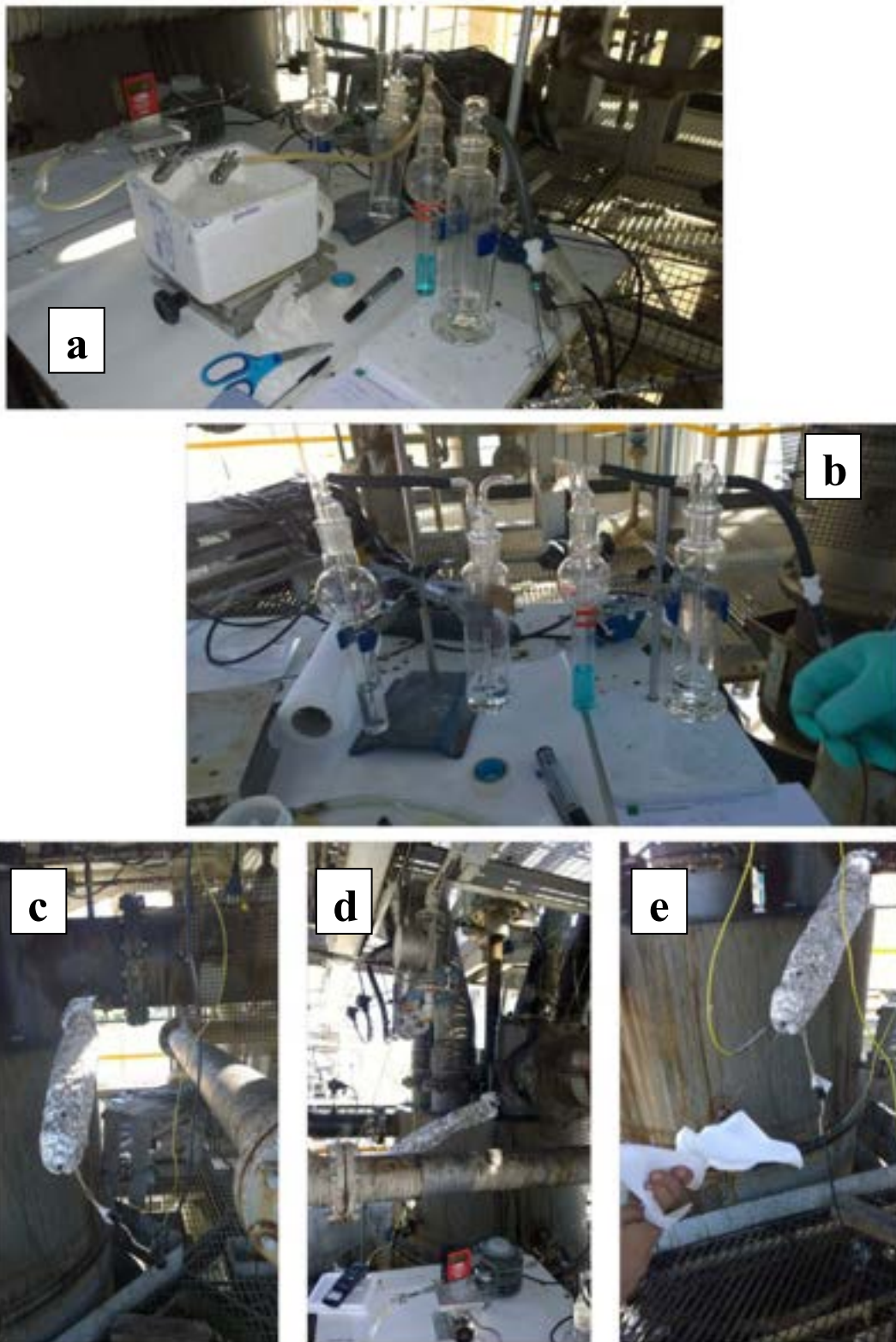


Figura 7a. Allestimento delle trappole e prelievo dei campioni relativi alla campagna del 27 luglio 2016: a. particolare delle trappole; b. Drechsel per la raccolta dei solfuri; c. camicia termostatica per il prelievo del tar; d. vista della zona di campionamento; e. Pulizia del punto di prelievo del TAR.



Figura 7b. Allestimento delle trappole e prelievo dei campioni relativi alla campagna del 27 luglio 2016: a. pulizia del punto di prelievo del TAR; b. prelievo del TAR; c-d. spurgo della linea di prelievo del TAR; e. valvola di prelievo.

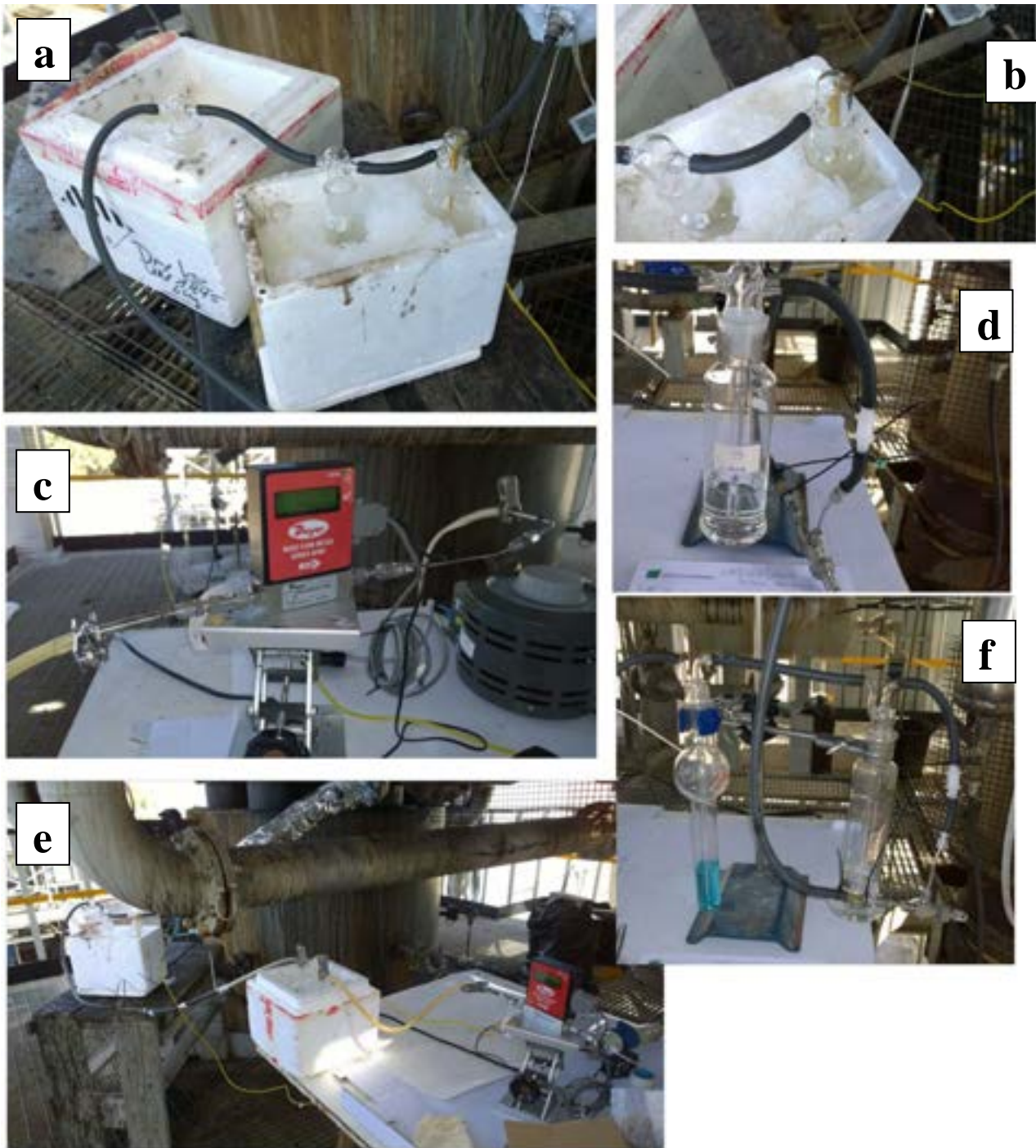


Figura 8. Allestimento delle trappole e prelievo dei campioni relativi alla campagna del 07 settembre 2016: a-b. particolare delle trappole per la raccolta del tar; c. totalizzatore di portata del gas; d. Drechsel per il campionamento del TAR; e. campionamento del TAR; f. Drechsel per raccolta dei solfuri e per la determinazione dell'umidità.

2.4 Risultati

2.4.1. Analisi dei contaminanti

Nella tabella seguente sono riportati i risultati delle analisi dei contaminanti, espressi come grammi per Nm³ di syngas.

Dato analitico	Campagna 1	Campagna 2	Campagna 3	Campagna 4
Data	19/05/2016	05/07/2016	27/07/2016	07/09/2016
Tempo di campionamento	30'	30'	30'	20'
Volume totale di gas raccolto	≈ 2.5 L	≈ 1.8 L	≈ 2.5 L	≈ 1.5 L
Contenuto di umidità	<1%	1.70%	0.75%	1.60%
Acidità totale	1.095	0.89	0.346	1.88
Contenuto di NH₃	n.d.	48	3.99	5.6
Solfuri come S	n.d.	5.72	0.10	8.36
Alogenuri	assenti	assenti	assenti	assenti
Odore	bruciato	solforoso	di oli essenziali	solforoso
Colore in NaOH	incolore	incolore	incolore	incolore

Tabella 1. Risultati delle analisi per la determinazione dei contaminanti e del contenuto di umidità.

2.4.2. Analisi dei macrocostituenti

Nella tabella seguente sono riportati i risultati delle analisi gascromatografiche dei macrocostituenti, espresse in % in volume del syngas secco. I dati sono la media di almeno 3 iniezioni per ciascuna miscela. L'ossigeno non è stato determinato, sia utilizzando He che N₂ come gas carrier, nel primo caso a causa della separazione non ottimale dei picchi di N₂ ed O₂, nel secondo caso a causa della bassa sensibilità del TCD dovuta a valori di termoconducibilità simili per i due gas. Per quanto riguarda le concentrazioni di H₂S e COS, le incertezze sui valori ottenuti sono dovute al fatto che la calibrazione dei due componenti è stata fatta con una sola miscela al 2% in volume, quindi molto più concentrata della quantità effettivamente presente nei campioni. La concentrazione dei componenti idrocarburici contenenti più di tre atomi di carbonio è stata espressa come concentrazione totale di C3+ (Tabella 2).

Campagna	1	2	3	4
Data prelievo	19/05/2016	05/07/2016	27/07/2016	07/09/2016
Componente	Amt (%vol)	Amt (%vol)	Amt (%vol)	Amt (%vol)
Alimentazione	biomassa	90% carbone colombiano + 10% biomassa	biomassa	carbone colombiano
H ₂	5.01	16.14	7.62	11.64
N ₂	67.70	51.45	51.54	59.07
O ₂	n.d.	n.d.	n.d.	n.d.
CO	22.20	16.46	31.70	13.69
C1	1.19	2.32	1.24	1.25
CO ₂	3.08	12.78	6.11	13.34
C2 ⁼	0.04	0.05	0.05	0.03
C2	0.08	0.20	0.08	0.09
C3 ⁼	0.03	0.05	0.03	0.02
C3	0.02	0.04	0.02	0.03
C3+	0.06	0.18	0.42	0.34
H ₂ S	n.p.	< 0.3	< 0.1	< 0.4
COS	n.p.	< 0.1	n.p.	< 0.01

Tabella 2. Risultati delle analisi gascromatografiche: n.d = non determinato; n.p. = non presente.

2.4.3. Analisi del TAR

I risultati ottenuti sono riassunti nella Tabella 3 e nelle Figure 9 e 10. Nella Figura 9, le sostanze identificate sono state riunite per gruppi (secondo il protocollo TAR dell'Energy project ERK6-CT1999-2002 [1]): acidi, zuccheri, aldeidi e chetoni, fenoli, furani, ossigenati misti, idrocarburi aromatici, PAHs (idrocarburi poliaromatici), aromatici contenenti azoto, che però non sono presenti in nessuno dei campioni analizzati. Nella Figura 10 sono invece riportati i confronti delle % in peso dei diversi gruppi di componenti, classificati

in base al numero di atomi di carbonio, secondo i requisiti per "Gaseous Fuels for TEDOM Engines", Regulation n° 61-0-0282-1.

La composizione e la distribuzione percentuale (% in peso) dei diversi costituenti del TAR per ciascun prelievo sono invece riportati nelle Tabelle 1A-4A in allegato, da cui emerge chiaramente la complessità del TAR, in termini sia di numero che di natura delle sostanze che lo compongono.

Data campionamento	19/05/2016	05/07/2016	27/07/2016	07/09/2016
Volume i-propanolo (mL)	150	225	225	225
Volume gas (L)	1.32	1.97	2.57	1.79
Solido recuperato per filtrazione (g)	-	0.0417	0.1972	0.0419
TAR dopo evaporazione in rotavapor (g)	0.2703	0.6237	3.5568	0.9292
TAR + solido (g)	0.2703	0.6654	3.7540	0.9711
TAR + solido (g/Nm ³)	205	338	1462	543

Tabella 3. Dati riassuntivi sulla quantità di TAR presente nel syngas.

Dall'analisi dei dati in tabella, si può notare come la quantità di TAR contenuta nel syngas sia diversa per le diverse campagne, verosimilmente a causa della diversa natura dell'alimentazione e delle condizioni di marcia dell'impianto. In particolare si può notare che la quantità di TAR risulta molto più elevata, sia in termini assoluti sia relativamente alla quantità di TAR insolubile in isopropanolo (Figura 11), nel campione raccolto il 27 luglio, per il quale ci sono anche state complicazioni durante il campionamento, in quanto il tubo di prelievo si tappava facilmente sebbene riscaldato a 200 °C (Figura 7a). Anche durante il campionamento del 7 settembre si sono avuti problemi dovuti ad un corto circuito che ha impedito il riscaldamento della linea di prelievo.

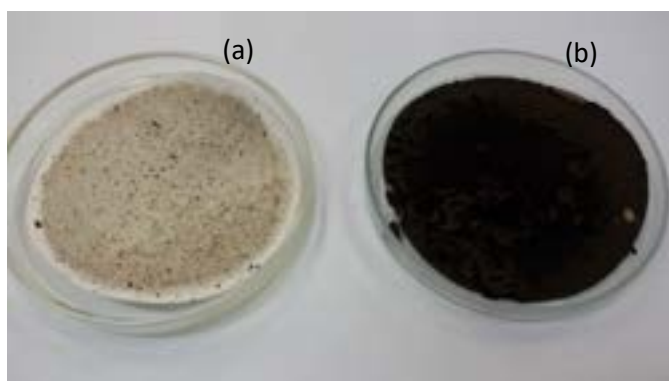


Figura 11. Residuo solido dopo filtrazione per i campioni della campagna del 05 luglio (a) e del 27 luglio (b).

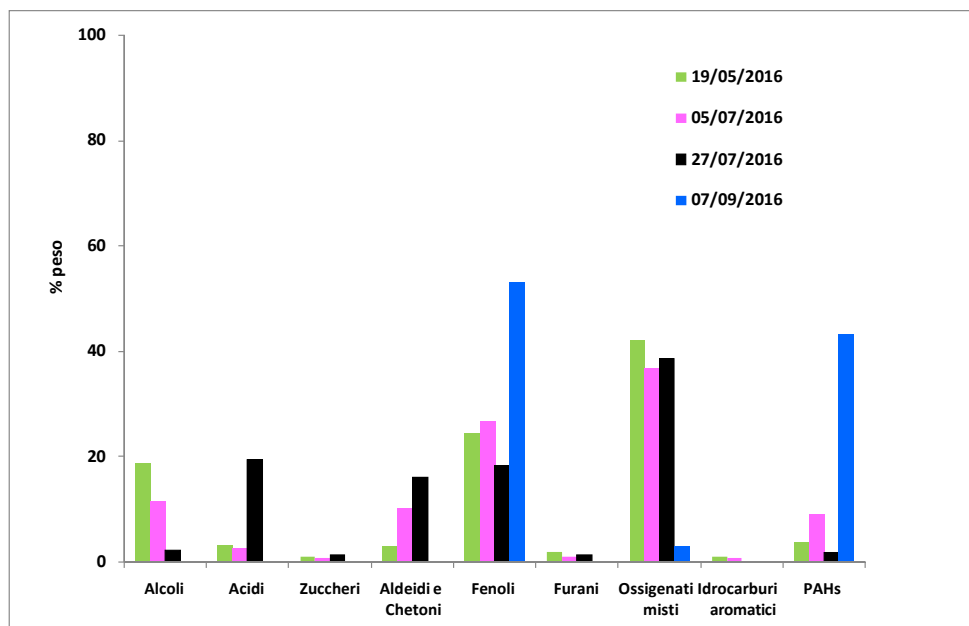


Figura 9. Confronto tra le composizioni del TAR dei diversi campionamenti. I componenti sono raggruppati secondo la classificazione riportata in [1].

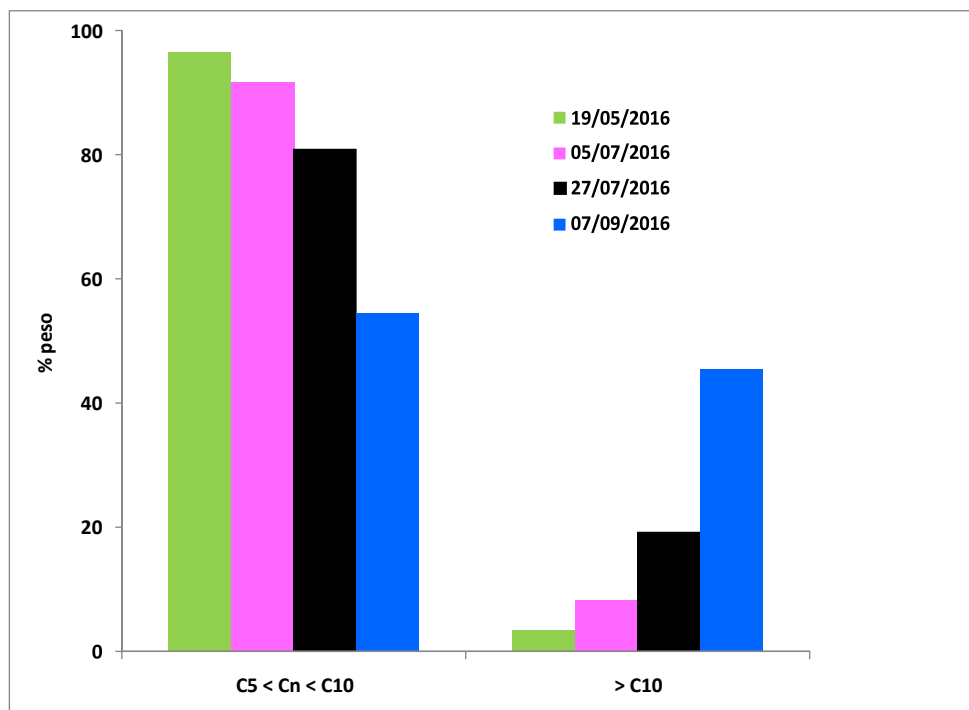


Figura 10. Confronto tra le composizioni del TAR dei diversi campionamenti. I componenti sono raggruppati in base al numero di atomi di carbonio, C_n , secondo i requisiti per "Gaseous Fuels for TEDOM Engines".

Dalle Figure 9 e 10 si può inoltre notare che i campioni raccolti durante le diverse campagne non solo differiscono nella quantità di TAR contenuta nel syngas, ma anche nella natura e nella concentrazione dei diversi componenti, come mostrato nelle Tabelle 1A-4A in allegato.

2.4.4. Altre analisi

Relativamente alla campagna di campionamento del 07 settembre 2016, sono state eseguite analisi aggiuntive. In particolare:

- su un campione prelevato per gorgogliamento in una Drechsel contenente isopropanolo posta sulla linea di prelievo non riscaldata del syngas, la stessa utilizzata per la raccolta dei campioni destinati all'analisi dei contaminanti. Questa prova è stata fatta per verificare la presenza di TAR nel syngas lontano dall'uscita del gassificatore. Dopo 30 min, non è stata osservata nessuna colorazione del solvente (Figura 11), in accordo con l'assenza di altre sostanze nella soluzione, come rivelato dall'analisi alla Gas-Massa. Tale risultato indica che, per la determinazione del TAR, il punto di prelievo del syngas deve essere vicino all'uscita del gassificatore, confermando la validità della procedura messa a punto sinora.



Figura 11. Drechsel contenente isopropanolo dopo gorgogliamento del syngas dalla linea di prelievo a freddo.

- su un campione liquido, viscoso e di colore scuro, raccolto a valle del filtro posto sulla linea di invio del syngas al motore. Su tale campione sono state effettuate delle analisi preliminari per la determinazione del contenuto di acqua, della composizione della fase organica, e della solubilità di quest'ultima in solventi quali CH_2Cl_2 e n-ottano (scelto come rappresentativo di un gasolio leggero). Per la determinazione del contenuto di acqua, il campione (0.6512 g) è stato trattato col rotavapor, aumentando gradualmente la temperatura fino a 90 °C, perdendo circa 0.1110 g. Tale perdita in peso, di circa il 17 %, può essere attribuita all'acqua, anche se non si può escludere un contributo dovuto all'evaporazione di componenti organici volatili. Due diverse porzioni del campione sono poi state disciolte in CH_2Cl_2 (campione nero, Figura 12) ed in n-ottano (campione giallo, Figura 12), nei quali sembrano totalmente miscibili; inoltre, la formazione di una superficie di separazione tra le due fasi organica e acquosa non è stata osservata in nessun caso. Le due soluzioni sono state analizzate alla Gas-Massa ed risultati sono riassunti nella Figura 13. Si può vedere che, indipendentemente dal colore, le due soluzioni presentano la stessa natura e una distribuzione molto simile dei composti. I dati completi sono mostrati nelle Tabelle allegate 5A e 6A per diclorometano e n-ottano, rispettivamente.

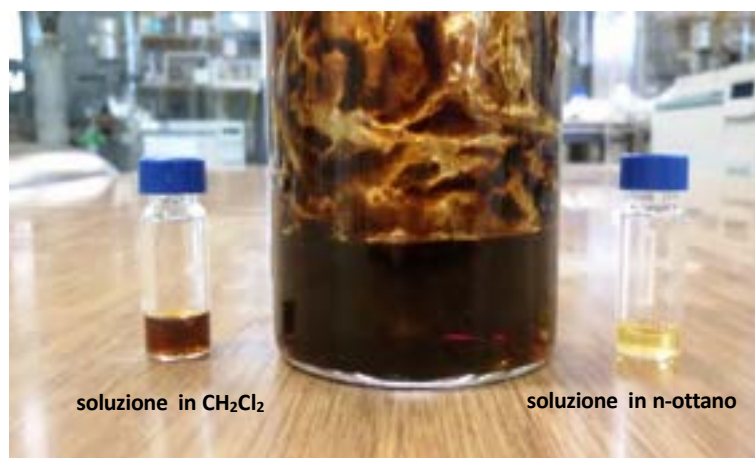


Figura 12. campione raccolto a valle del filtro posto sulla linea di invio del syngas al motore.

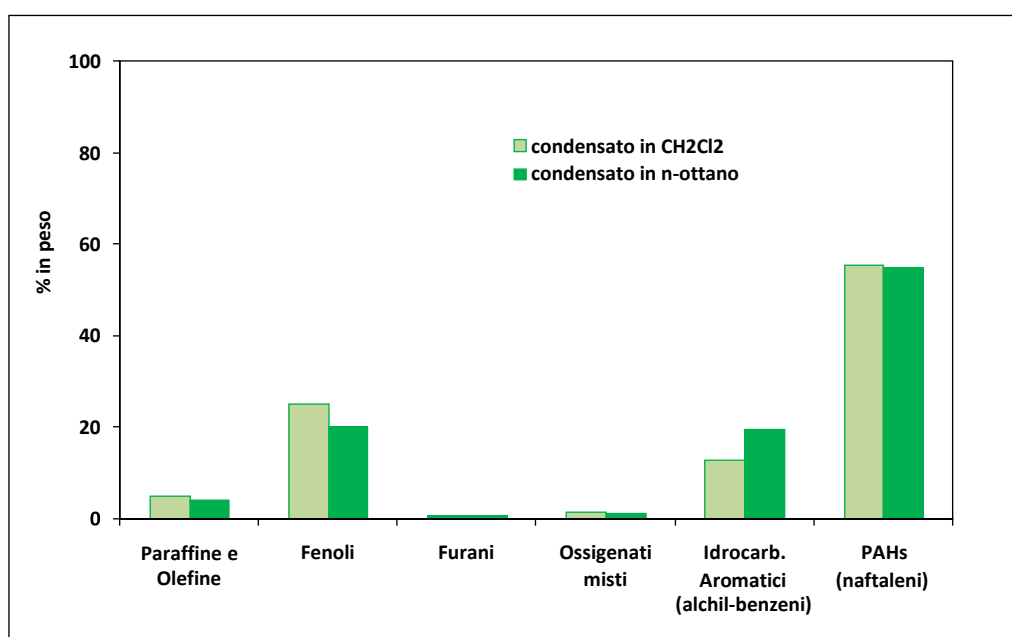


Figura 13. Composizione del campione raccolto a valle del filtro posto sulla linea di invio del syngas al motore.

- su un campione solido (residuo carbonioso, Figura 14) proveniente dal tubo principale di uscita dal gassificatore che è stato ripulito dai depositi carboniosi accumulatisi nel tempo. Una porzione di tale campione è stata estratta con CH₂Cl₂. Come atteso, la quantità solubile è stata molto bassa. I risultati dell'analisi GC-MS sono riportati nella Tabella 7A in allegato.

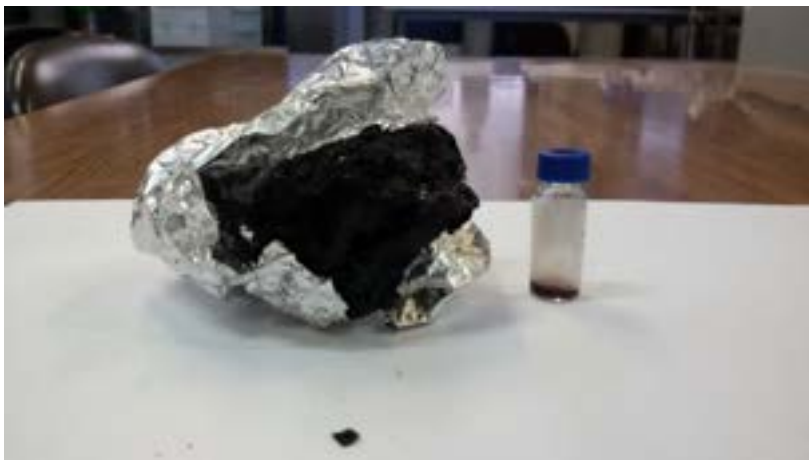


Figura 14. Residuo carbonioso solido proveniente dal tubo principale di uscita del gassificatore dopo pulizia dello stesso.

3 Conclusioni

Durante questa attività sono state effettuate 4 campagne di campionamento del syngas proveniente dalla gassificazione di carbone e biomasse, al fine di determinarne la composizione in termini di macrocostituenti e principali contaminanti. I risultati ottenuti indicano che le procedure di prelievo e di analisi messe a punto sono appropriate per il raggiungimento degli obiettivi prefissati. Tuttavia alcuni aspetti possono essere ulteriormente migliorati, in particolare l'individuazione di ulteriori punti di prelievo. Analisi preliminari del liquido condensato a valle del filtro sulla linea di invio del syngas al motore hanno infatti mostrato la presenza di diversi composti organici presenti nel TAR. Ciò potrebbe suggerire la predisposizione di una presa di campionamento a valle dello scrubber, allo scopo di determinare il contenuto di umidità e la natura dei composti organici ancora presenti nel syngas. Dal punto di vista analitico, l'analisi gascromatografica deve essere ulteriormente ottimizzata in relazione alla determinazione delle concentrazioni di O_2 , H_2S e COS .

4 Riferimenti bibliografici

1. J.P.A. Neeft ed altri, "Guideline for Sampling and Analysis of TAR and Particles in Biomass Producer Gases", Energy project ERK6-CT1999-2002.

5 Curriculum del gruppo di ricerca

Università degli Studi di Cagliari
Dipartimento di Scienze Chimiche e Geologiche

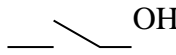
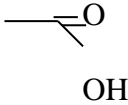
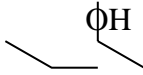
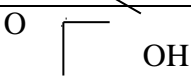

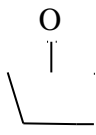
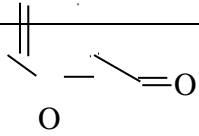
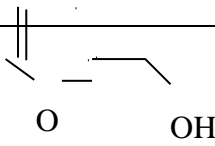
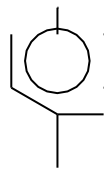
Gruppo di ricerca "Chimica Industriale"
(M. G. Cutrufello, Roberto Monaci, Elisabetta Rombi)

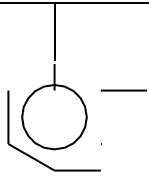
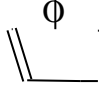
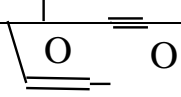
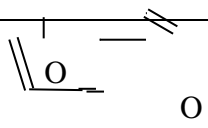
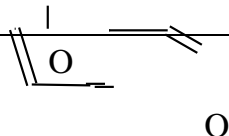
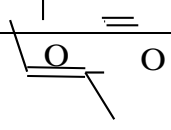
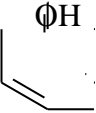
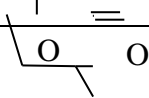
Gruppo di ricerca "Equilibri in soluzione e composti di coordinazione"
(Tiziana Pivetta)

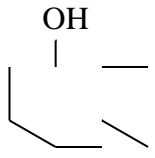
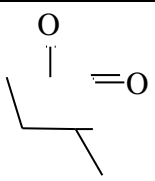
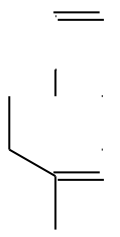
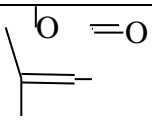
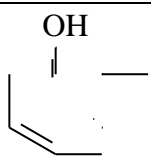
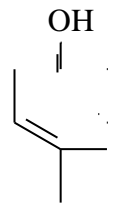
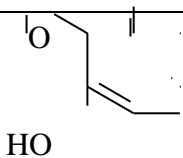
Lo staff permanente dei due laboratori è costituito da cinque ricercatori, affiancati da due tecnici. L'attività scientifica del gruppo di "Chimica Industriale" è indirizzata allo studio dei solidi (in particolare ossidi metallici, metalli supportati, supporti ad alta area superficiale) per applicazioni in adsorbimento e catalisi. Il gruppo ha competenze che vanno dalla sintesi e caratterizzazione al testing delle loro performance in applicazioni di potenziale interesse industriali. Nel campo della caratterizzazione, anche in collaborazione con altri gruppi di ricerca del dipartimento, vengono studiate le proprietà della struttura, morfologia, tessitura, redox e acido-base dei materiali con diverse tecniche quali: diffrazione di raggi X, spettroscopia IR, microscopia elettronica, adsorbimento fisico di azoto, tecniche a temperatura programmata, microcalorimetria di adsorbimento. In alcuni casi, i catalizzatori sono caratterizzati anche dopo l'uso per verificare eventuali modificazioni delle proprietà superficiali in seguito alla reazione e/o per analizzare la natura e la composizione di eventuali depositi carboniosi (coke). Lo studio delle prestazioni dei materiali è condotto in impianti da laboratorio che impiegano reattori o adsorbitori a letto. I campi di applicazione vanno dall'impiego di zuccheri da materie prime rinnovabili per l'ottenimento di combustibili e chemical commodities, ai processi di purificazione e conversione di syngas; in particolare si può citare la rimozione da correnti di idrogeno di CO (per via catalitica) e di H₂S (per adsorbimento reattivo), la produzione di CH₄ ed il sequestro della CO₂. L'attività scientifica del gruppo di "Equilibri in soluzione e composti di coordinazione" è principalmente rivolta alla sintesi e caratterizzazione di complessi metallici con attività antitumorale, all'analisi chemiometrica e all'analisi ambientale. Alcune tematiche svolte in quest'ultimo ambito, hanno riguardato l'analisi dell'impianto di trattamento delle acque provenienti dai bacini degli sterili della miniera di Masua, l'analisi spettrofotometrica NIR/MIR di latte proveniente da aziende lattiero-casearie e relativo iter all'interno del laboratorio di analisi, la valutazione delle caratteristiche qualitative di alcuni siti dell'acquifero sotterraneo insediato nell'anello metallifero dell'iglesiente, i piani di caratterizzazione dell'area del Sulcis Iglesiente in relazione ai metodi analitici per la valutazione di un campione di suolo.

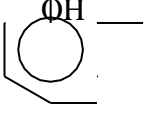
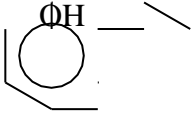
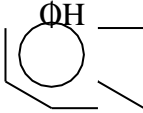
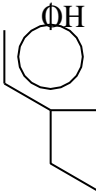
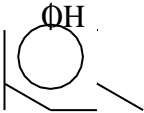
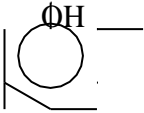
6 Allegati

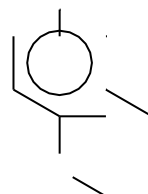
Tabella 1A. Analisi GC-MS del TAR 19-05-2016

Formula	Molecole	Developed Formula	%
C_3H_8O	1-propanol		18.70
$C_2H_4O_2$	acetic acid		3.28
$C_4H_{10}O$	2-Butanol		0.19
$C_3H_6O_2$	1-hydroxy-2-propanone		5.48
$C_4H_8O_2$	3-hydroxy-tetrahydrofuran		0.59
C_5H_8O	Cyclopentanone		0.02
$C_5H_4O_2$	Furfural		0.30
$C_5H_6O_2$	Furfuryl alcohol		0.13
C_8H_{10}	p-xylene		1.09

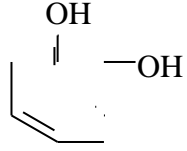
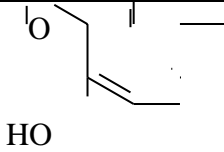
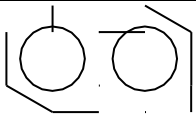
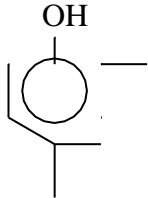
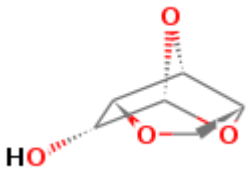
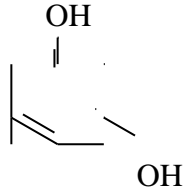
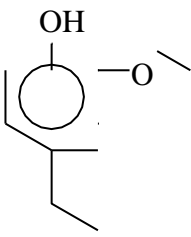
C_8H_{10}	o-xylene		0.02
C_6H_8O	2-methyl-2-cyclopenten-1-one		0.08
$C_4H_4O_2$	2(5H)-Furanone		0.70
$C_6H_6O_2$	2-Acetyl-furan		0.08
$C_6H_6O_2$	5-Methyl-2-Furfural		0.13
$C_5H_6O_2$	3-Methyl-2(5H)-Furanone		0.04
C_6H_6O	phenol		3.30
$C_4H_6O_3$	2-Hydroxy-2-3(H)-furanone		0.04

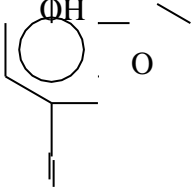
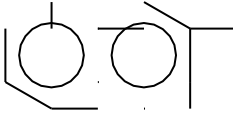
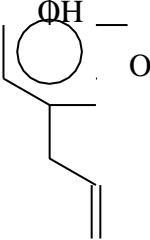
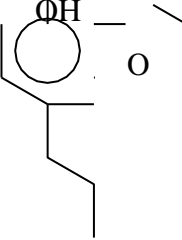
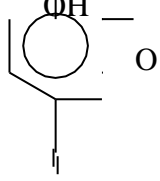
$C_8H_{16}O$	2.3-dimethyl-cyclohexanol		0.03
$C_6H_8O_2$	3-methyl-1,2-cyclopentanedione		2.93
$C_{10}H_{16}$	D-Limonene		0.06
$C_5H_6O_2$	4-methyl-5H-furan-2-one		0.05
C_7H_8O	2-methyl-phenol		2.81
C_7H_8O	4-Methyl-phenol		0.03
$C_7H_8O_2$	2-Methoxy-Phenol		5.50

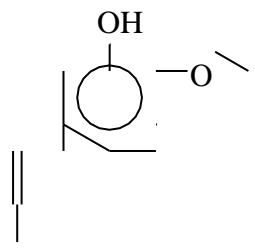
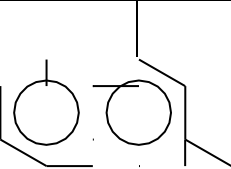
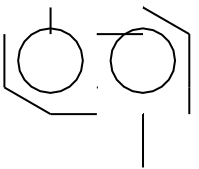
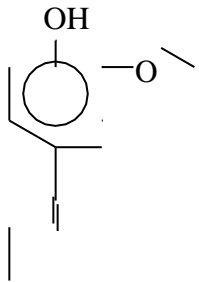
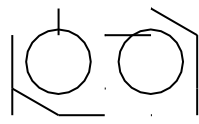
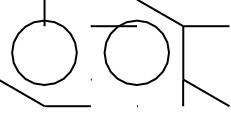
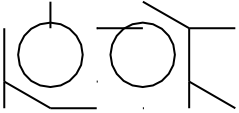
$C_8H_{10}O$	2,6-Dimethyl-Phenol		8.32
$C_8H_{10}O$	2-Ethyl-Phenol		0.07
$C_8H_{10}O$	2,3-Dimethyl -Phenol		0.61
$C_8H_{10}O$	4-Ethyl-Phenol		3.51
$C_8H_{10}O$	3,5-Dimethyl -Phenol		2.82
$C_8H_{10}O$	2,5-Dimethyl -Phenol		0.03



$C_8H_{10}O_2$	3-Methyl-4-Methoxy-Phenol	OH O	0.08
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$C_6H_6O_2$	1,2-Benzendiol (catechol)		2.79
$C_8H_{10}O_2$	4-Methyl-2-Methoxy-Phenol		10.77
$C_{10}H_8$	Naphthalene		1.32
$C_9H_{12}O$	2,4,6-Trimethyl-Phenol		0.07
$C_6H_8O_4$	1,4:3,6-Dianhydro- α -d-glucopyranose		1.11
$C_7H_8O_2$	5-methyl-1,3-benzendiol (3,5-dihydroxy-toluene)		0.16
$C_9H_{12}O_2$	4-Ethyl-2-Methoxy-Phenol		8.30

$C_9H_{10}O_2$	4-vinyl-guaiacol		0.25
$C_{11}H_{10}$	2-methyl- Naphthalene		0.12
$C_{10}H_{12}O_2$	Eugenol		0.22
$C_{10}H_{14}O_2$	Dihydroeugenol		3.57
$C_8H_8O_3$	Vanillin		0.10

$C_{10}H_{12}O_2$	5-(1-propenyl)-2-methoxy-phenol		1.58
$C_{12}H_{12}$	2,6-dimethyl-naphthalene		0.11
$C_{12}H_{12}$	1,4-dimethyl-naphthalene		0.18
$C_{10}H_{12}O_2$	4-(1-propenyl)-2-methoxy-phenol (ISOEUGENOL)		6.34
$C_{12}H_{12}$	1,6-dimethyl-naphthalene		0.11
$C_{12}H_{12}$	2,3-dimethyl-naphthalene		0.14
$C_{13}H_{14}$	2,3,6-Trimethyl-naphthalene		0.10

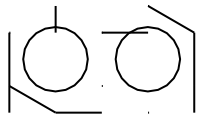
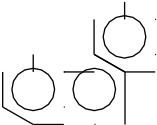
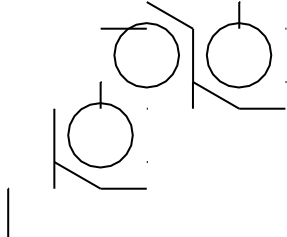
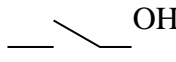
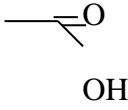
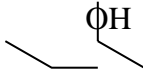
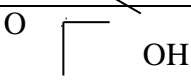
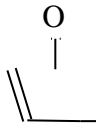
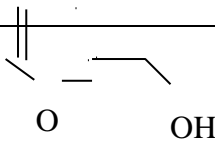
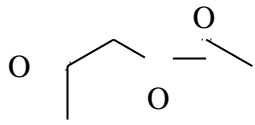
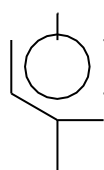
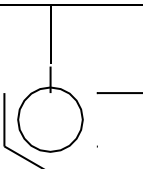

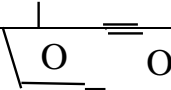
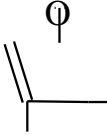
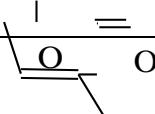
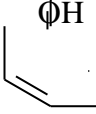
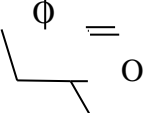

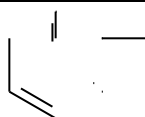
$C_{13}H_{14}$	1,6,7-Trimethyl-naphthalene		0.12
$C_{14}H_{10}$	phenanthrene		1.47
$C_{18}H_{18}$	7-isopropyl-1-methyl-phenanthrene		0.07

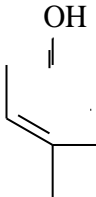
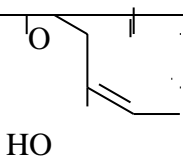
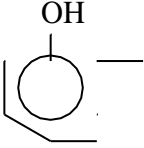
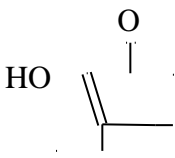
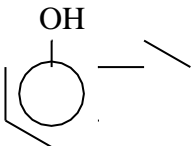
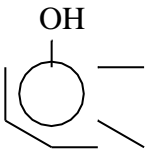
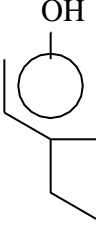
Tabella 2A. Analisi GC-MS del TAR 05-07-16

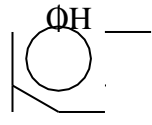
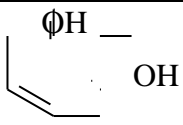
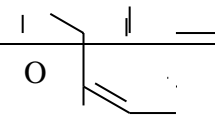
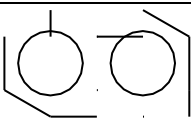
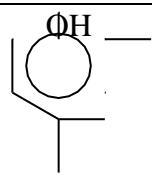
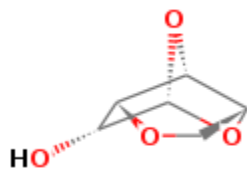
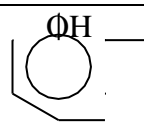
Formula	Molecole	Developed Formula	%
C_3H_8O	1-propanol		11.31
$C_2H_4O_2$	acetic acid		2.70
$C_4H_{10}O$	2-Butanol		0.14
$C_3H_6O_2$	1-hydroxy-2-propanone		2.24
C_5H_6O	2-Cyclopenten-1-one		1.69
$C_5H_6O_2$	Furfuryl alcohol		0.08
$C_5H_8O_3$	Acetoxyacetone		1.01
C_8H_{10}	p-xylene		0.46
C_8H_{10}	o-xylene		0.37

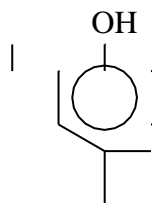
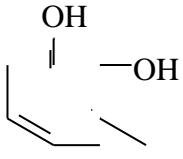
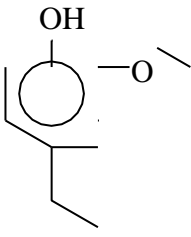
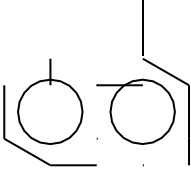
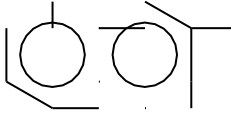
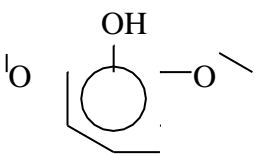
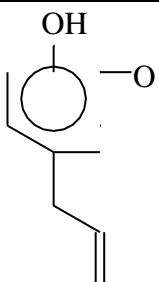
C_6H_8O	2-methyl-2-cyclopenten-1-one		0.80
$C_4H_4O_2$	2(5H)-Furanone		0.60
$C_6H_6O_2$	3-Methyl-2-cyclopenten-1-one		1.30
$C_5H_6O_2$	3-Methyl-2(5H)-Furanone		0.46
C_6H_6O	phenol		3.49
$C_6H_8O_2$	3-methyl-1,2-cyclopentanedione		2.37
$C_7H_{10}O$	2,3-dimethyl-2-cyclopenten-1-one		0.75

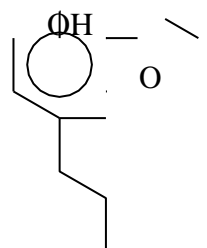
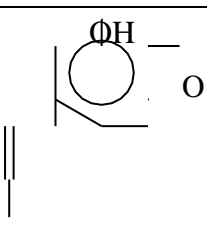
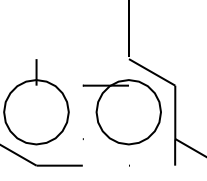
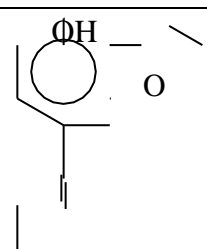
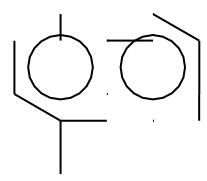



C ₇ H ₈ O	2-methyl-phenol	OH	2.76
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C_7H_8O	4-Methyl-phenol		5.45
$C_7H_8O_2$	2-Methoxy-Phenol		6.47
$C_8H_{10}O$	2,6-Dimethyl-Phenol		0.85
$C_7H_{10}O_2$	Ethyl-2-hydroxy-2-cyclopenten-1-one		1.18
$C_8H_{10}O$	2-Ethyl-Phenol		0.58
$C_8H_{10}O$	2,3-Dimethyl -Phenol		2.58
$C_8H_{10}O$	4-Ethyl-Phenol		2.61

$C_8H_{10}O$	2,5-Dimethyl -Phenol		0.48
$C_6H_6O_2$	1,2-Benzendiol (catechol)		2.46
$C_8H_{10}O_2$	4-Methyl-2-Methoxy-Phenol		8.31
$C_{10}H_8$	Naphthalene		1.00
$C_9H_{12}O$	2,4,6-Trimethyl-Phenol		0.71
$C_6H_8O_4$	1,4:3,6-Dianhydro- α -d-glucopyranose		0.89
$C_9H_{12}O$	2-Ethyl-6-Methyl-Phenol		1.21

$C_9H_{12}O$	2-Ethyl-4-Methyl-Phenol		0.43
$C_7H_8O_2$	3-methyl-1,2-benzendiol		3.19
$C_9H_{12}O_2$	4-Ethyl-2-Methoxy-Phenol		5.57
$C_9H_{10}O_2$	1-methyl- Naphthalene		2.11
$C_{11}H_{10}$	2-methyl- Naphthalene		1.18
$C_8H_{10}O_3$	2,6-dimethoxy-phenol		4.93
$C_{10}H_{12}O_2$	Eugenol		2.25

$C_{10}H_{14}O_2$	Dihydroeugenol		1.54
$C_{10}H_{12}O_2$	5-(1-propenyl)-2-methoxyphenol		1.17
$C_{12}H_{12}$	2,6-dimethyl-naphthalene		0.97
$C_{10}H_{12}O_2$	4-(1-propenyl)-2-methoxyphenol (ISOEUGENOL)		4.66
$C_{12}H_{12}$	1,5-dimethyl-naphthalene		1.53
$C_{13}H_{14}$	2,3,6-Trimethyl-naphthalene		0.74

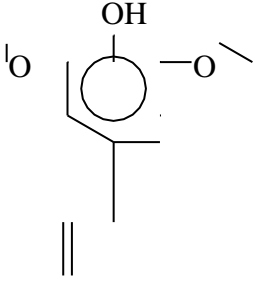
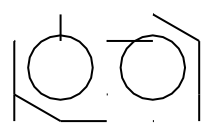
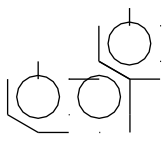
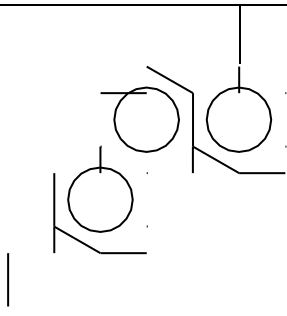
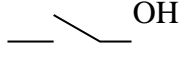

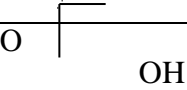
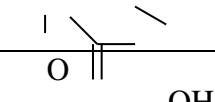
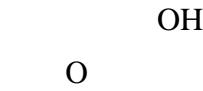
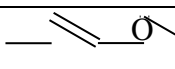
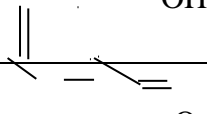
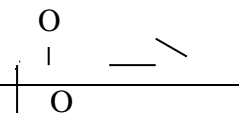
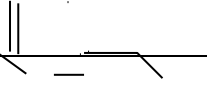
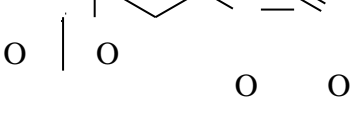
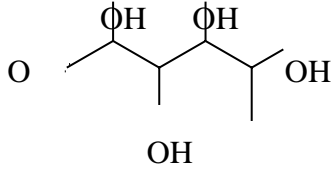
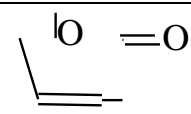
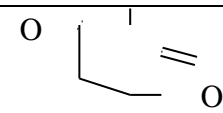
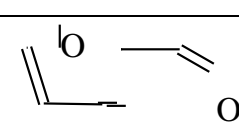
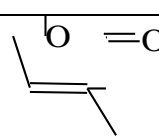
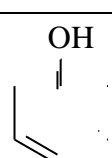
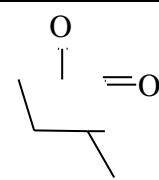
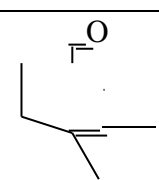
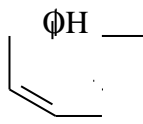
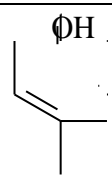
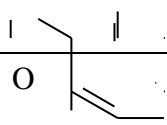
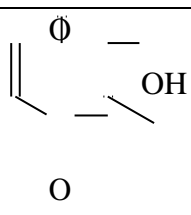
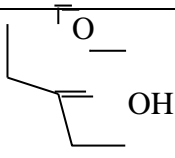
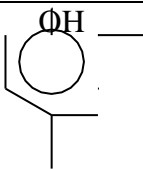
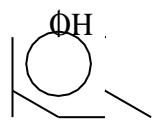
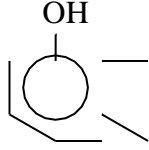
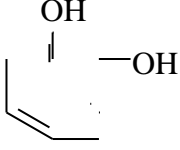
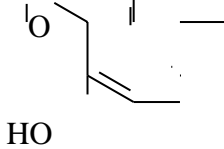
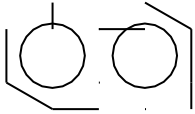
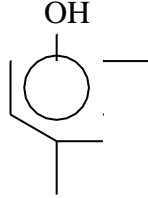
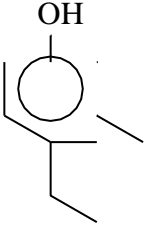
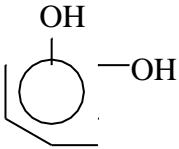
$C_{11}H_{14}O_3$	MethoxyEugenol		0.93
$C_{13}H_{14}$	1,6,7-Trimethyl-naphthalene		0.99
$C_{14}H_{10}$	phenanthrene		0.39
$C_{18}H_{18}$	7-isopropyl-1-methyl-phenanthrene		0.12

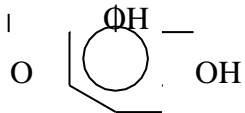
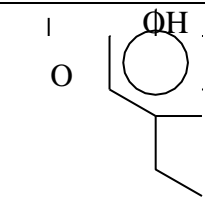
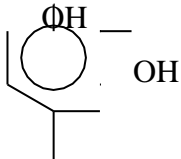
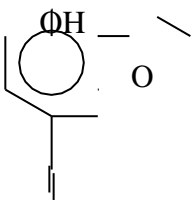
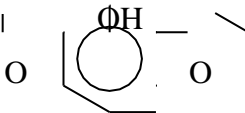
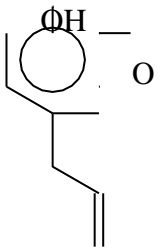
Tabella 3A. Analisi GC-MS del TAR 27-07-2016

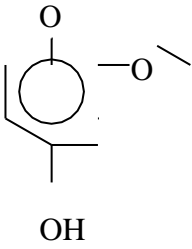
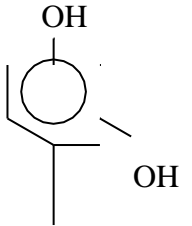
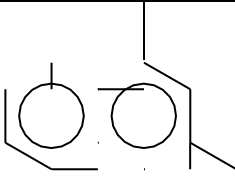
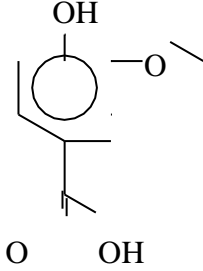
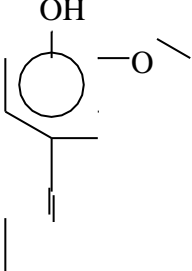
Formula	Molecole	Developed Formula	%
C_3H_8O	1-propanol		0.49
$C_2H_4O_2$	acetic acid		19.33
$C_3H_6O_2$	1-hydroxy-2-propanone		5.92
$C_3H_6O_3$	Methyl-glycolate		0.91
$C_4H_8O_2$	1-hydroxy-2-butanone		0.68
$C_4H_6O_2$	Crotonic acid		0.13
$C_5H_4O_2$	Furfural		2.96
$C_4H_4O_3$	1,2-Ethandiol-monoacetate		0.43
$C_5H_6O_2$	Furfuryl alcohol		1.93
$C_6H_{10}O_4$	1,2-Ethandiol-diacetate		0.87

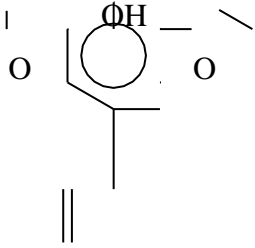
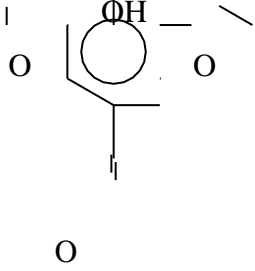
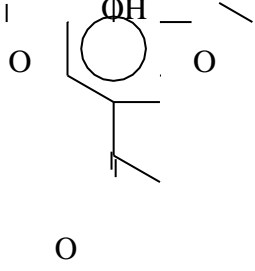
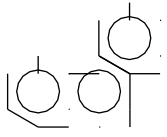
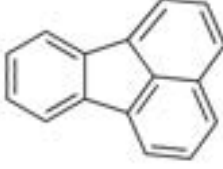
$C_6H_{12}O_5$	6-deoxy-D-Galactose		0.10
$C_4H_4O_2$	2(5H)-Furanone		1.15
$C_5H_6O_2$	1,2-cyclopentanedione		0.81
$C_6H_6O_2$	5-Methyl-2-Furfural		1.51
$C_5H_6O_2$	3-Methyl-2(5H)-Furanone		0.38
C_6H_6O	phenol		1.75
$C_6H_8O_2$	3-methyl-1,2-cyclopentanedione		2.94
$C_7H_{10}O$	2,3-dimethyl-2-cyclopenten-1-one		0.57

C_7H_8O	2-methyl-phenol		1.44
C_7H_8O	4-Methyl-phenol		2.82
$C_7H_8O_2$	2-Methoxy-Phenol		3.28
$C_6H_6O_3$	Maltol		1.37
$C_7H_{10}O_2$	3-Ethyl-2-hydroxy-2-cyclopenten-1-one		0.79
$C_8H_{10}O$	2,4-Dimethyl -Phenol		1.14
$C_8H_{10}O$	3,5-Dimethyl -Phenol		1.17

$C_8H_{10}O$	2,3-Dimethyl -Phenol		0.63
$C_6H_6O_2$	1,2-Benzendiol (catechol)		2.80
$C_8H_{10}O_2$	4-Methyl-2-Methoxy-Phenol		3.81
$C_{10}H_8$	Naphthalene		0.44
$C_9H_{12}O$	2,4,6-Trimethyl-Phenol		0.62
$C_9H_{12}O_2$	4-Ethyl-3-Methyl-Phenol		0.75
$C_7H_8O_2$	3-methyl-1,2-benzenediol		1.97

$C_7H_8O_3$	3-methoxy-1,2-benzenediol		3.56
$C_7H_8O_2$	4-Ethyl-2-methoxy-phenol (4-Ethyl-guaiacol)		1.77
$C_7H_8O_2$	4-methyl-1,2-benzenediol		1.84
$C_9H_{10}O_2$	2-Methoxy-4-vinylphenol (4-vinyl-guaiacol)		1.64
$C_{11}H_{10}$	2,6-dimethoxy-phenol		8.53
$C_{10}H_{12}O_2$	Eugenol		0.71

$C_{11}H_{10}$	3,4-dimethoxy-phenol		1.42
$C_8H_{10}O_2$	4-ethyl-1,3-benzenediol		1.42
$C_{12}H_{12}$	2,6-dimethyl-naphthalene		0.53
$C_8H_8O_4$	Vanillic acid		4.93
$C_{10}H_{12}O_2$	4-(1-propenyl)-2-methoxy-phenol (ISOEUGENOL)		2.20

$C_{11}H_{14}O_3$	MethoxyEugenol		2.10
$C_9H_{10}O_4$	4-Hydroxy-3,5-dimethoxybenzaldehyde		0.71
$C_{10}H_{12}O_4$	3,5-dimethoxy-4-hydroxyacetophenone		1.83
$C_{14}H_{10}$	phenanthrene		0.64
$C_{16}H_{10}$	fluoranthene		0.15

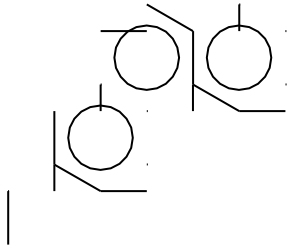
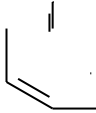
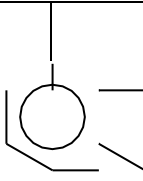
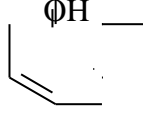
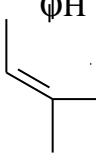
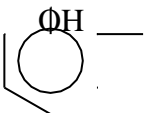
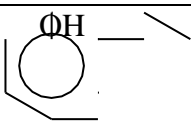
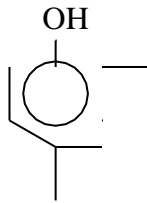
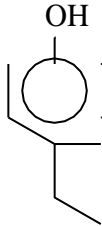
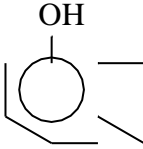
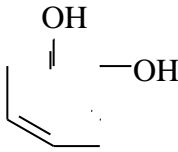
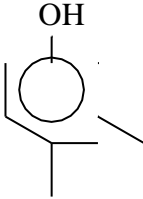

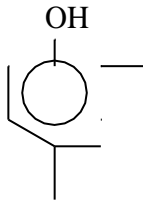
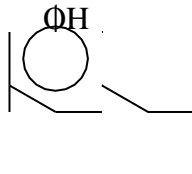
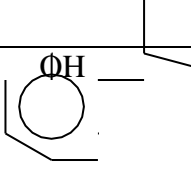
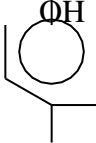
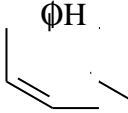
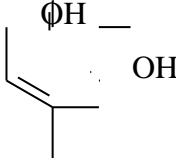
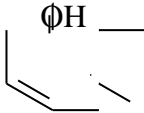
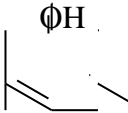
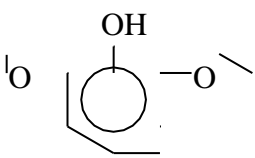
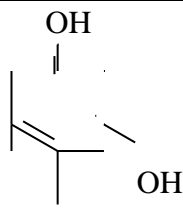
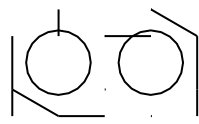
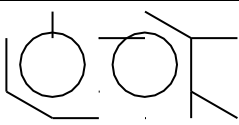
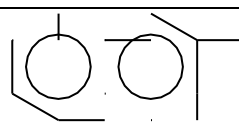
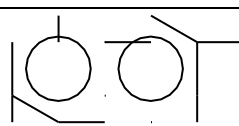
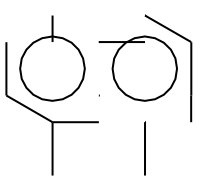
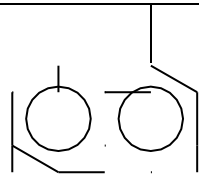
$C_{18}H_{18}$	7-isopropyl-1-methyl-phenanthrene	 <p>The image shows the skeletal structure of 7-isopropyl-1-methylphenanthrene. It consists of three fused benzene rings in an angular arrangement. A methyl group is attached to the first ring, and an isopropyl group is attached to the seventh ring.</p>	0.10
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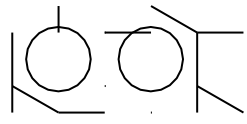
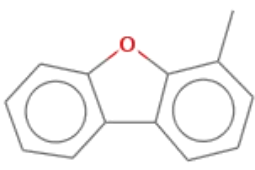
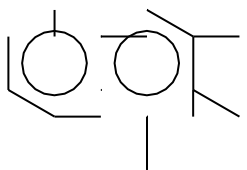
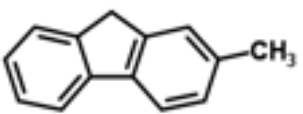
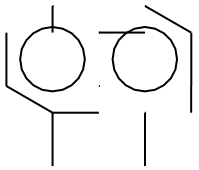
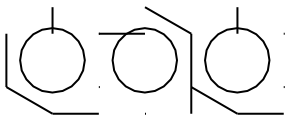
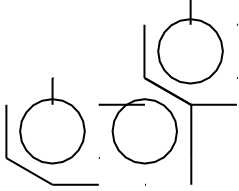
Tabella 4A. Analisi GC-MS del TAR-07-09-16

Formula	Molecole	Developed Formula	%
C_6H_6O	phenol	OH 	4.15
C_9H_{12}	1,2,3-Trimethylbenzene		0.30
C_7H_8O	2-methyl-phenol	ΦH 	2.51
C_7H_8O	4-Methyl-phenol	ΦH 	5.00
$C_8H_{10}O$	2,6-dimethyl-phenol	ΦH 	0.61
$C_8H_{10}O$	2-Ethyl-Phenol	ΦH 	0.74

$C_8H_{10}O$	2,4-Dimethyl -Phenol		3.34
	4-Ethyl-Phenol		3.44
$C_8H_{10}O$	2,3-Dimethyl -Phenol		0.60
$C_6H_6O_2$	1,2-Benzendiol (catechol)		2.51
$C_8H_{10}O$	3,4-Dimethyl -Phenol		1.04
$C_{10}H_8$	Naphthalene		0.95
$C_9H_{12}O$	2,4,6-Trimethyl-Phenol		1.70

$C_9H_{12}O$	3-Ethyl-5-methyl-phenol		0.89
$C_9H_{12}O$	2-(1-methylethyl)-phenol		1.07
$C_6H_6O_2$	hydroquinone	 OH	3.06
$C_6H_6O_2$	1,3-benzendiol (Resorcinol)	 OH	5.18
$C_7H_8O_2$	4-methyl-1,2-benzendiol	 OH	1.75
$C_7H_8O_2$	2-methyl-1,3-benzendiol	 OH	4.00
$C_7H_8O_2$	5-methyl-1,3-benzendiol (3,5-dihydroxy-toluene)	 OH	8.38

$C_{11}H_{10}$	2,6-dimethoxy-phenol		3.14
$C_8H_{10}O_2$	4,5-dimethyl-1,3-benzendiol		3.29
$C_{12}H_{12}$	1,6-dimethyl-naphthalene		2.75
$C_{12}H_{12}$	2,3-dimethyl-naphthalene		4.57
$C_{12}H_{12}$	2,7-dimethyl-naphthalene		3.95
$C_{12}H_{12}$	2,6-dimethyl-naphthalene		3.39
$C_{13}H_{14}$	1,4,5-Trimethyl-naphthalene		2.45
$C_{13}H_{14}$	1,6,7-Trimethyl-naphthalene		5.94

$C_{13}H_{14}$	2,3,6-Trimethyl-naphthalene		2.14
$C_{13}H_{10}O$	4-Methyl-dibenzofuran		2.12
$C_{14}H_{16}$	1,2,3,4-Tetramethyl-naphthalene		2.59
$C_{14}H_{12}$	2-Methyl-9H-fluorene		2.12
$C_{14}H_{16}$	1,4,5,8-Tetramethyl-naphthalene		3.56
$C_{14}H_{10}$	Antracene		2.76
$C_{15}H_{12}$	4-methyl-phenanthrene		0.91

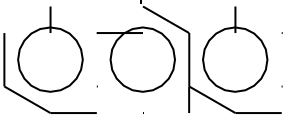
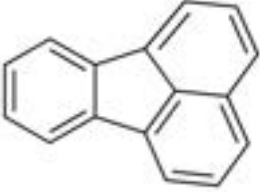
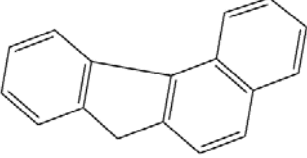
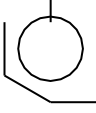
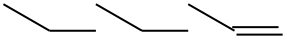
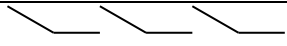
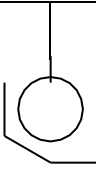
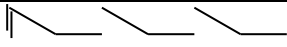
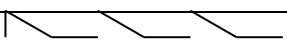
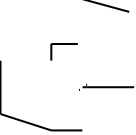
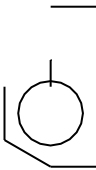
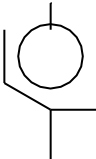
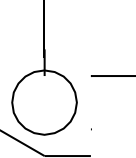
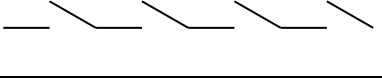
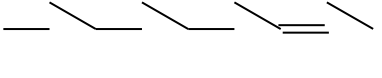
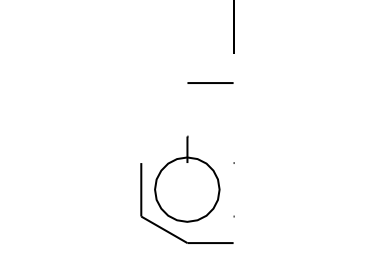
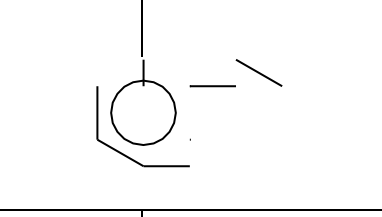
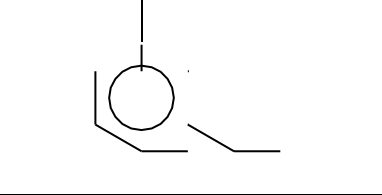
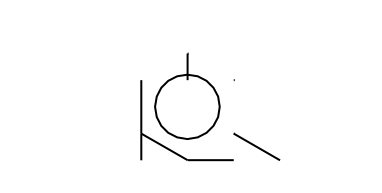
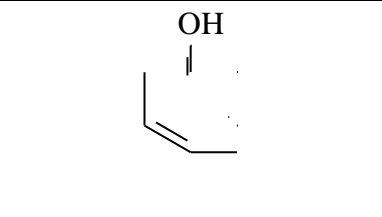
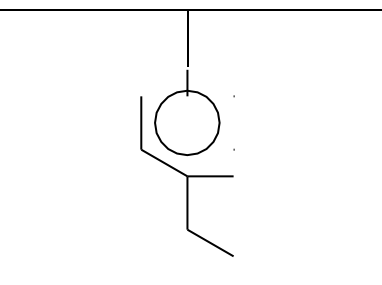
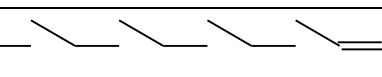
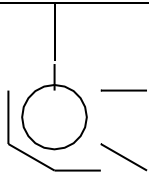
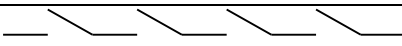
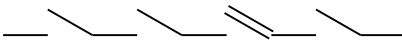
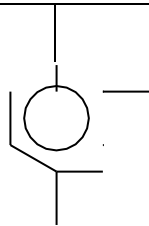
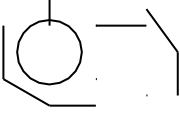
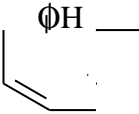
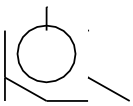
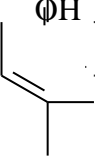
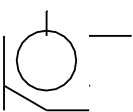
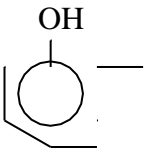
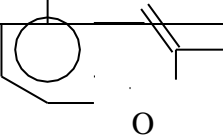
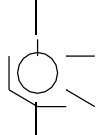
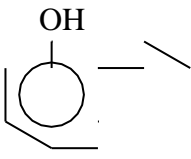
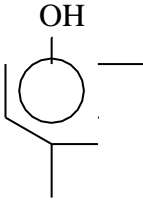
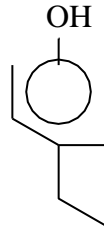
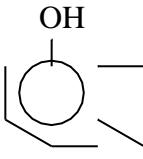
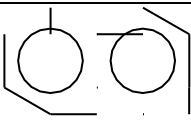
$C_{15}H_{12}$	9-methyl- Antracene		2.56
$C_{16}H_{10}$	fluorantene		0.40
$C_{17}H_{12}$	3,4-benzofluorene		0.12

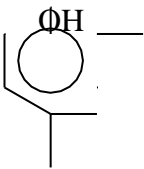
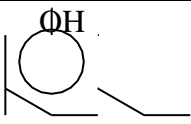
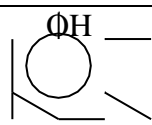
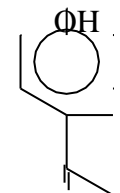
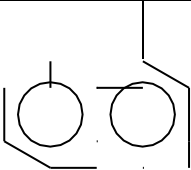
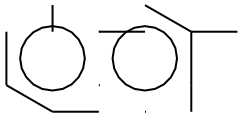
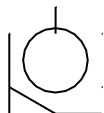
Tabella 5A. Analisi GC-MS del condensato raccolto a valle del filtro disciolto in CH₂Cl₂


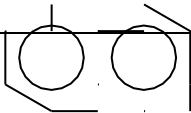
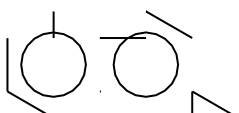
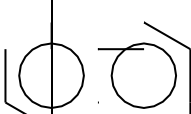
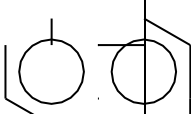
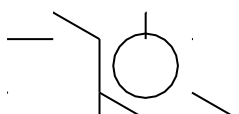
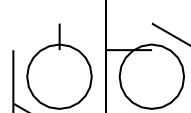
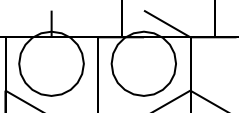
Formula	Molecole	Developed Formula	%
C ₆ H ₆	benzene		0.06
C ₇ H ₁₄	1-heptene		0.03
C ₇ H ₁₆	n-heptane		0.07
C ₇ H ₈	Toluene		0.49
C ₈ H ₁₆	1-octene		0.12
C ₈ H ₁₈	n-octane		0.27
C ₈ H ₁₄	Methyl-Ethyl-Cyclopentene		0.07
C ₈ H ₁₀	Ethyl-Benzene		0.38
C ₈ H ₁₀	p-xylene		1.37
C ₈ H ₁₀	o-xylene		0.79

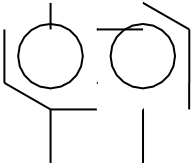
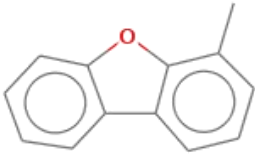
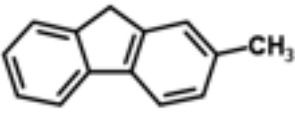
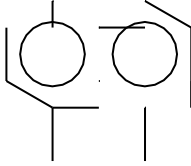
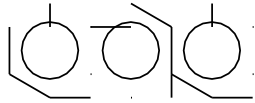
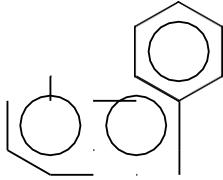
C_9H_{20}	nonane		0.72
C_8H_{18}	2-nonene		0.17
C_9H_{12}	Propyl-benzene		0.36
C_9H_{12}	1-Ethyl-2-Methyl-benzene		0.93
C_9H_{12}	1-Ethyl-3-Methyl-benzene		0.51
C_9H_{12}	1,3,5-Trimethyl-Benzene		0.71
C_6H_6O	phenol		0.62
C_9H_{12}	1-Ethyl-4-Methyl-benzene		0.43
$C_{10}H_{20}$	1-Decene		0.95

C_9H_{12}	1,2,3-Trimethyl-Benzene		1.57
C_9H_{22}	Decane		1.57
$C_{10}H_{20}$	4-Decene		1.01
C_9H_{12}	1,2,4-Trimethyl-Benzene		1.70
C_9H_{10}	Indane		1.14
C_7H_8O	2-methyl-phenol		2.69
$C_{10}H_{14}$	1-Ethyl-3,5-dimethyl-Benzene		0.89
C_7H_8O	4-Methyl-phenol		2.46
$C_{10}H_{14}$	1-Ethyl-2,4-dimethyl-Benzene		0.56

$C_8H_{10}O$	2,6-dimethyl-phenol		1.54
C_9H_8O	2-methyl-Benzofuran		0.58
$C_{10}H_{14}$	1,2,3,4-Tetramethyl-Benzene		0.67
$C_8H_{10}O$	2-Ethyl-Phenol		0.93
$C_8H_{10}O$	2,4-Dimethyl -Phenol		4.78
	4-Ethyl-Phenol		5.76
$C_8H_{10}O$	2,3-Dimethyl -Phenol		0.68
$C_{10}H_8$	Naphthalene		2.63

$C_9H_{12}O$	2,4,6-Trimethyl-Phenol		2.16
$C_9H_{12}O$	3-Ethyl-5-methyl-phenol		1.47
$C_9H_{12}O$	2,3,5-Trimethyl-Phenol		1.82
$C_9H_{10}O_2$	4-hydroxy-3-Methyl-acetophenone	 O	1.35
$C_9H_{10}O_2$	1-methyl- Naphthalene		3.66
$C_{11}H_{10}$	2-methyl- Naphthalene		2.69
$C_{12}H_{16}$	1-(2-butenyl)-2,3-dimethyl-Benzene		1.35

$C_{12}H_{12}$	1-Ethyl-naphthalene		2.68
$C_{12}H_{12}$	2,7-dimethyl-naphthalene		3.24
$C_{12}H_{12}$	1,3-dimethyl-naphthalene		3.39
$C_{12}H_{12}$	1,5-dimethyl-naphthalene		4.90
$C_{12}H_{12}$	1,4-dimethyl-naphthalene		4.02
$C_{13}H_{18}$	1,2,3,4-Tetrahydro-1,6,8-trimethyl-naphthalene		3.01
$C_{13}H_{14}$	1,4,6-Trimethyl-naphthalene		2.85
$C_{13}H_{14}$	2,3,6-Trimethyl-naphthalene		2.28

$C_{13}H_{14}$	1,4,5-Trimethyl-naphthalene		3.74
$C_{13}H_{10}O$	4-Methyl-dibenzofuran		2.37
$C_{14}H_{12}$	2-Methyl-9H-fluorene		2.61
$C_{14}H_{16}$	1,4,5,8-Tetramethyl-naphthalene		3.88
$C_{14}H_{10}$	Anthracene		3.44
$C_{15}H_{12}$	4-methyl-phenanthrene		1.31

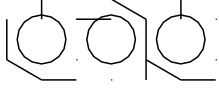
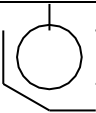
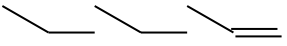
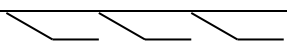
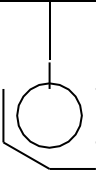
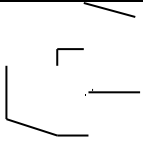

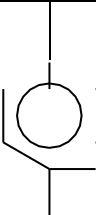
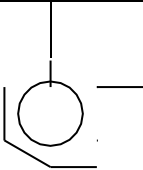
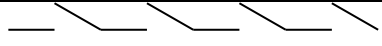
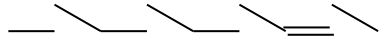
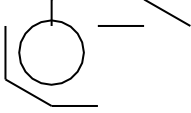
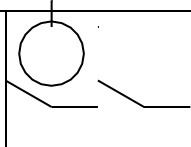
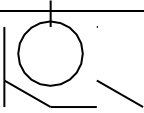
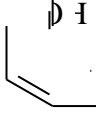
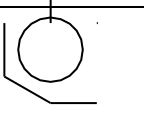
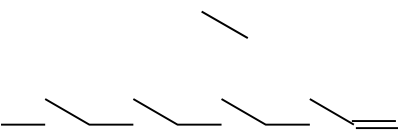
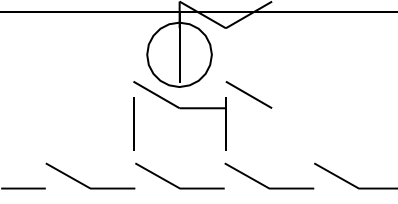
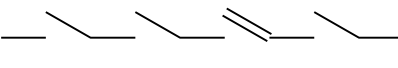
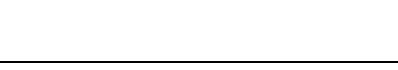
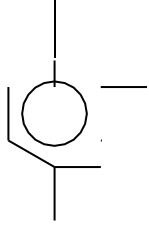
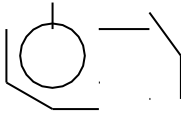
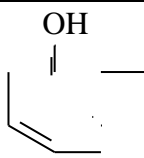
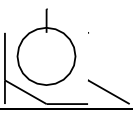
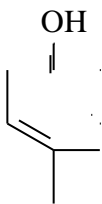
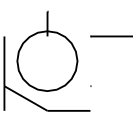
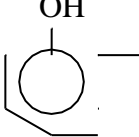
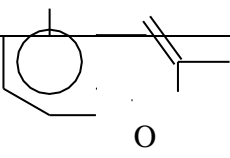
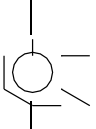
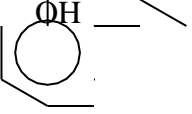
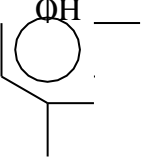
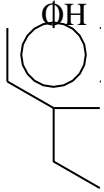
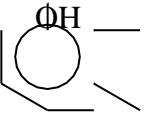

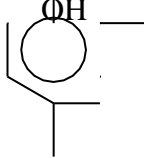
$C_{15}H_{12}$	1-methyl-Antracene		1.59
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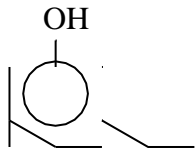
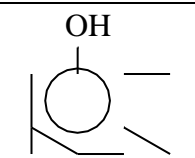
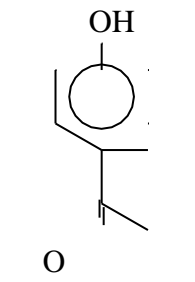
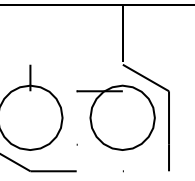
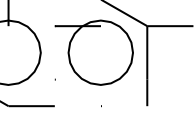
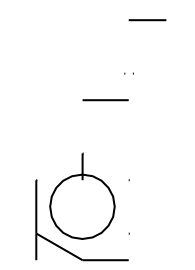
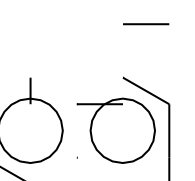
Tabella 6A. Analisi GC-MS del condensato raccolto a valle del filtro disciolto in n-ottano

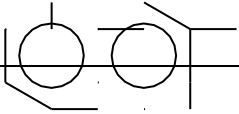
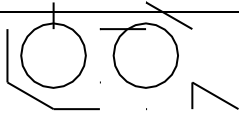
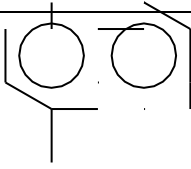
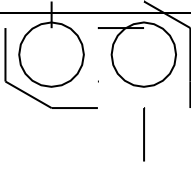
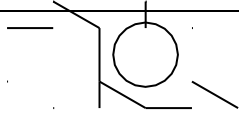
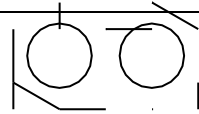
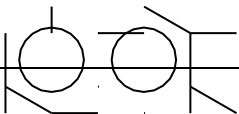
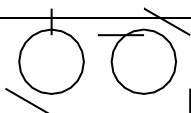
Formula	Molecole	Developed Formula	%
C_6H_6	benzene		0.03
C_7H_{14}	1-heptene		0.00
C_7H_{16}	n-heptane		0.03
C_7H_8	Toluene		10.68
C_8H_{14}	Methyl-Ethyl-Cyclopentene		0.48
C_8H_{10}	Ethyl-Benzene		0.00
C_8H_{10}	p-xylene		0.96
C_8H_{10}	o-xylene		0.03
C_9H_{20}	nonane		0.03
C_8H_{18}	2-nonene		0.53

C_9H_{12}	1-Ethyl-2-Methyl-benzene		0.69
C_9H_{12}	1-Ethyl-3-Methyl-benzene		0.36
C_9H_{12}	1,3,5-Trimethyl-Benzene		0.60
C_6H_6O	phenol		0.44
C_9H_{12}	1-Ethyl-4-Methyl-benzene		0.34
$C_{10}H_{20}$	1-Decene		0.68
C_9H_{12}	1,2,3-Trimethyl-Benzene		1.36
C_9H_{22}	Decane		1.51
$C_{10}H_{20}$	4-Decene		0.80

C_9H_{12}	1,2,4-Trimethyl-Benzene		1.22
C_9H_{10}	Indane		0.69
C_7H_8O	2-methyl-phenol		1.71
$C_{10}H_{14}$	1-Ethyl-3,5-dimethyl-Benzene		0.75
C_7H_8O	4-Methyl-phenol		2.07
$C_{10}H_{14}$	1-Ethyl-2,4-dimethyl-Benzene		0.54
$C_8H_{10}O$	2,6-dimethyl-phenol		1.32
C_9H_8O	2-methyl-Benzofuran		0.51

$C_{10}H_{14}$	1,2,3,4-Tetramethyl-Benzene		0.56
$C_8H_{10}O$	2-Ethyl-Phenol		0.70
$C_8H_{10}O$	2,4-Dimethyl -Phenol		4.26
	4-Ethyl-Phenol		4.41
$C_8H_{10}O$	2,3-Dimethyl -Phenol		0.48
$C_{10}H_8$	Naphthalene		2.37
$C_9H_{12}O$	2,4,6-Trimethyl-Phenol		1.99

$C_9H_{12}O$	3-Ethyl-5-methyl-phenol		1.18
$C_9H_{12}O$	2,3,5-Trimethyl-Phenol		1.54
$C_9H_{10}O_2$	4-hydroxy-3-Methyl-acetophenone		1.20
$C_9H_{10}O_2$	1-methyl- Naphthalene		3.42
$C_{11}H_{10}$	2-methyl- Naphthalene		2.50
$C_{12}H_{16}$	1-(2-butenyl)-2,3-dimethyl-Benzene		1.27
$C_{12}H_{12}$	1-Ethyl-naphthalene		2.51

$C_{12}H_{12}$	2,7-dimethyl-naphthalene		3.10
$C_{12}H_{12}$	1,3-dimethyl-naphthalene		3.26
$C_{12}H_{12}$	1,5-dimethyl-naphthalene		5.01
$C_{12}H_{12}$	1,4-dimethyl-naphthalene		3.90
$C_{13}H_{18}$	1,2,3,4-Tetrahydro-1,6,8-trimethyl-naphthalene		2.97
$C_{13}H_{14}$	1,4,6-Trimethyl-naphthalene		2.84
$C_{13}H_{14}$	2,3,6-Trimethyl-naphthalene		2.01
			

$C_{13}H_{14}$	1,4,5-Trimethyl-naphthalene		3.81
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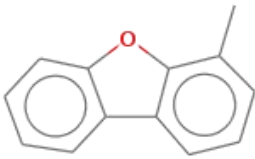
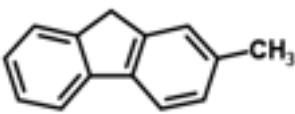
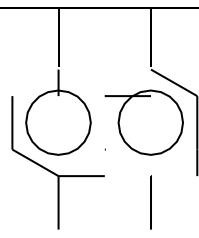
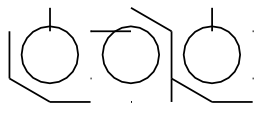
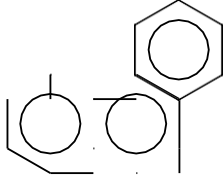
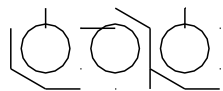
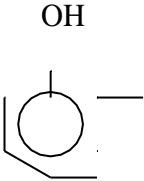
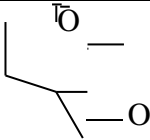
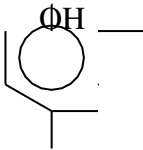
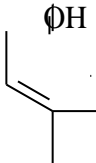
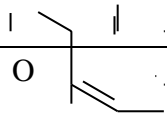
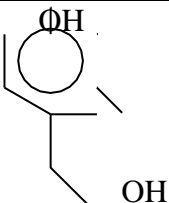
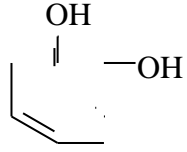
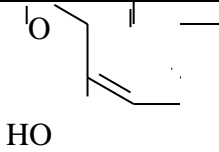
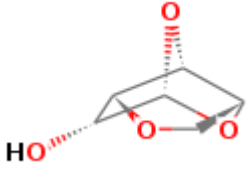
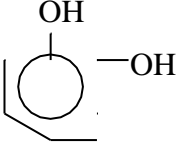
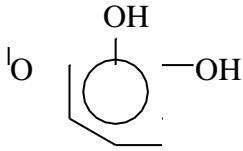
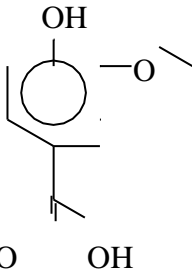
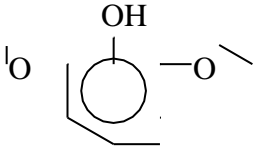
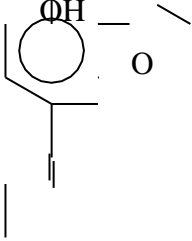
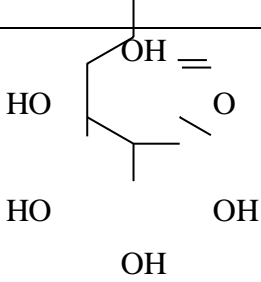
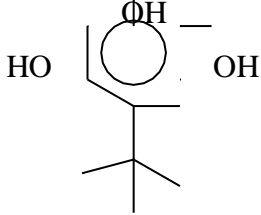
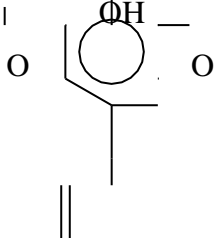
$C_{13}H_{10}O$	4-Methyl-dibenzofuran		2.44
$C_{14}H_{12}$	2-Methyl-9H-fluorene		2.72
$C_{14}H_{16}$	1,4,5,8-Tetramethyl-naphthalene		4.26
$C_{14}H_{10}$	Antracene		3.72
$C_{15}H_{12}$	4-methyl-phenanthrene		1.38
$C_{15}H_{12}$	1-methyl-Antracene		1.85

Tabella 7A. Analisi GC-MS del residuo carbonioso solido proveniente dal tubo principale di uscita del gassificatore dopo pulizia dello stesso.

Formula	Molecole	Developed Formula	%
$C_8H_{10}O$	2,6-dimethyl-phenol		17.62
$C_6H_7O_2$	3-Methyl-1,2-cyclopentadienone		1.46
$C_7H_8O_2$	2-methyl-1,4-benzenediol		0.59
C_7H_8O	4-Methyl-phenol		0.94
$C_7H_8O_2$	2-Methoxy-Phenol		1.19
$C_8H_{10}O_2$	4-Ethyl-1,3-benzenediol		1.78

$C_6H_6O_2$	1,2-Benzendiol (catechol)		3.13
$C_8H_{10}O_2$	4-Methyl-2-Methoxy-Phenol		2.33
$C_6H_8O_4$	1,4:3,6-Dianhydro- α -d-glucopyranose		1.60
$C_7H_8O_2$	3-methyl-1,2-benzenediol		1.76
$C_7H_8O_3$	3-methoxy-1,2-benzenediol		4.24
$C_8H_8O_4$	Vanillic acid		17.85
$C_{11}H_{10}$	2,6-dimethoxy-phenol		11.53

$C_{10}H_{12}O_2$	4-(1-propenyl)-2-methoxyphenol (ISOEUGENOL)		4.18
$C_6H_{12}O_6$	D-Allose		5.30
$C_{10}H_{14}O_3$	5- <i>t</i> -butyl-1,2,3-trimethylbenzotriolo		8.28
$C_{11}H_{14}O_3$	Methoxy-eugenol		16.24