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ALCOHOL CRISIS IN BRAZIL:
THE SEARCH FOR ALTERNATIVES

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ALCOHOL CRISIS IN BRAZIL: THE SEARCH FOR ALTERNATIVES

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ABSTRACT

The ethanol shortage forecast of one billion liters, through 1990, forced government agencies and private organizations to search for an emergency solution which could guarantee fuel supply for the present 4,2 million ethanol fueled vehicles.

The evaluation of viable alternatives in the short term led the federal government to decrease, from 22% to 12% (and to 0% in certain areas), the ethanol content of gasohol; add 5% gasoline to the ethanol fuel and implement the use of a 60% ethanol/33% methanol/7% gasoline blend in selected regions of Brazil. This paper discusses the effects of these alternatives in terms of fuel utilization and air pollution.

In conclusion, the addition of gasoline to ethanol fuel and ethanol reduction in gasohol represent a risk to engine durability and reliability and result in a significant increase of pollutant emissions. The large scale use of the ethanol/methanol/gasoline blend has shown very good results, in terms of utilization and pollution emissions.

The use of this blend is the only known alternative which gives great flexibility to the management and recovery of the National Alcohol Program without placing the Motor Vehicle Pollution Control Program at risk.

1. INTRODUCTION

Due to the fall of approximately 50% in sugar cane prices between 1980 and 1988, areas dedicated to sugar cane plantation decreased in Brazil, particularly between 1987 and 1989. Consequently, ethanol production was exceeded by the consumption growth in 1989/1990 (1). Having to face the reality of a one billion liter ethanol shortage through 1990, the federal government established a task force composed of government agencies, research institutions, the motor industry, ethanol producers and Petrobrás (the state oil company which is responsible for ethanol distribution). This task force was asked to evaluate viable alternatives, other than ethanol rationing, in order to alleviate a shortage which, inevitably, would result in undesirable social effects, such as lack of transport, a black market in ethanol,

illegal fuel storage, use of improvised fuel blends, uncontroled engine conversions to gasohol etc.
The task force came out with two initial emergency recommendations:

1. a reduction of anhydrous ethanol content in gasohol from 22% to a minimum of 12% by volume; and

2. the addition of up to 5% by volume of gasoline in the hydrated ethanol fuel.

Since the practical effect of the two first recommendations, in terms of ethanol economy, would not be sufficient to overcome the shortage, a third alternative, considering the use of methanol as a suplementary alcohol source, was placed for evaluation.

To ascertain the feasibility of using methanol, an intensive research program was launched involving, principally, CETESB (the Environmental Protection Agency for the State of São Paulo) and the Brazilian motor industry.

At the very beginning of the research program CETESB defined two basic requirements for any fuel containing methanol:

a) no special tuning, recalibrations or conversions should be necessary for the engines; and

b) vehicle emissions should not be higher and/or more harmful to public health and the environment than those resulting from the use of gasohol or ethanol fuel .

The purpose of these requirements was to avoid environmental and public health risks, to allow for fuel use reversibility and to guarantee the attainment of the Motor Vehicle Emission Control Program goals (PROCONVE)(2) without the need of any change of specifications for the in-use vehicles.

Additionally, it is important to recognize that the consumer population had no responsibility for the ethanol shortage and therefore should not be penalized by any fuel change related costs.

The research program involving methanol use was successful and an alternative to ethanol fuel was found. This new fuel, a blend of 60% hydrated ethanol - 33% methanol- 7% gasoline (by volume), is substantially similar to ethanol fuel. This paper discusses the air pollution and vehicle-related effects of the alternatives adopted in Brazil to overcome the ethanol shortage.

2. THE USE OF METHANOL BLENDS

A full evaluation of a new fuel should ideally consider and analyze all risks related to fuel production, storage, transportation, handling and use. Due to the emergency situation, the first research work was directed toward fuel specification and measurement of vehicle exhaust emissions, evaporative emissions and fuel economy.

Although information concerning the use of methanol as an alternative fuel can be easily found, it was clear that the available data would only be a starting point, since as Brazilian conditions required a particular use of methanol (i.e. in engines designed for ethanol and gasohol).

Considering that the stoichiometric air-fuel ratios (A/F) and the heat values are increasing for methanol, ethanol and gasoline, respectively (table 1), theoretically an adequate blend of methanol and gasoline might be substantially similar to ethanol fuel and could be used with the same A/F requirements in an engine designed for ethanol use (3).

TABLE 1 - FUELS PROPERTIES

	LOWER HEAT VALUE (kcal/kg)	STOICH. A/F (kg/kg)	VISCOSITY (cSt)	DENSITY (kg/l)
Methanol	4 708	6.4	0.75	0.79
Anhyd. Eth.	6 405	9.0	1.5	0.79
Hydr. Eth.	5 926	8.3	-	0.80
Gasoline	10 205	14.8	0.6	0.74
70 M/30 G	6 357	8.9	-	0.77
60E/33M/7G(*)	5 823	8.2	-	0.79

(*) Considering hydrated ethanol

As a first approach, the proportion of methanol and gasoline was based on the A/F ratios and the heat values only. For a first evaluation of the theoretical reasoning, a blend of 70M/30G was tested in an alcohol vehicle, simulating a complete ethanol substitution. Following the same line of reasoning, other blends were tested.

The initials "E", "M" and "G" refer to percentage by volume of ethanol, methanol and gasoline, respectively.

The first test results, indicated that viscosity and volatility of methanol significantly affect a carburetor's fuel delivery, especially for the alcohol engines, resulting in richer A/F mixtures (i.e. more fuel than required) and in a threefold increase in carbon monoxide (CO) emission.

Therefore it was necessary to correct, empirically, the blending proportions to allow for a real A/F delivery that could match the one specified for the original fuel. Additional binary and tertiary blends were tested and it became clear that the blend 60E/33M/7G showed the best results in terms of similarity with ethanol fuel and the greatest potential for ethanol substitution.

It is interesting to note that methanol and gasoline, in the existing proportions, tend to compensate each other's effects. Methanol addition to ethanol results in a lean A/F and a lower heat value. Because methanol has a lower viscosity than ethanol, these effects are partially overcome by the higher carburetor's fuel supply. On the other hand, gasoline addition to ethanol results in a richer A/F and an increase in the heat value.

An important characteristic of this blend is the Reid Vapour Pressure which is about 80% higher than that of ethanol fuel. Although this characteristic improves cold start (which means less exhaust emissions and better fuel economy), it also increases evaporative emissions, particularly, in pre-1990 model year vehicles, which were not equiped with evaporative control systems.

The tests were carried out on a chassis dynamometer and the vehicles were submitted to the 1975 U.S.FTP (Federal Test Procedure - cold and hot start urban driving cycle) for light duty vehicles. Measurements of CO, total hydrocarbons (HC),nitrogen oxides(NOx), carbon dioxide (CO2), total aldehydes (MBTH -spectrofotometry method), formaldehyde and acetaldehyde (DNPH -gas chromatography method), alcohols (gas chromatography) and fuel economy, were made. Evaporative emission tests were conducted according to the U.S. Federal Test SHED Procedure, corrected for alcohols use (4).

In addition to CETESB's work, GENERAL MOTORS, FIAT, FORD, VOLKSWAGEN and the carburetor manufacturers, WEBER and BROSOL, also contributed to this research, by testing additional vehicles in laboratory and in the field, by evaluating the effect of methanol use on materials and by proposing the tolerance range of blend constituents.

Table 2 shows the exhaust emission and fuel economy data obtained with seven vehicles running on blend 60E/33M/7G and ethanol fuel (3).

The vehicles were designed originally for ethanol fuel and, before the tests, when necessary, were adjusted to manufacturers specifications.

It is noteworthy that out of the seven vehicles, only the four 1990 model year were designed to attain the first stage Brazilian emission limits which are, for exhaust emission, 24 g/km CO, 2.1 g/km HC, 2,0 g/km NOx and 3,0% CO at idle; for evaporative emission the legal limit is 6 g/test. These limits are in effect until December 31st, 1991, when the second stage of PROCONVE will be phased place, reducing pollutant emissions substantially.

Results expressed in terms of percentage indicate data variation in comparison with the baseline ethanol fuel.

TABLE 2 - METHANOL BLEND INFLUENCE ON EXHAUST EMISSION

	Nº OF TESTS	IDLE CO %	FUEL ECONOMY km/l	EMISSIONS - g/km CO	CO2	HC	NOx	FORMALD.	ACETALD	TOTAL ALDEHYD.	ETHANOL
PARATI 1.6 L/88	3	1.6	8.63	9.32	161	1.78	1.33	-	-	0.090*	-
AP 1600-WEBER 14.000 km	4	-28%	-4%	+5%	-2%	-21%	+17%	-	-	-	-
GOL 1.6 L/88	2	1.6	7.37	18.32	146	2.16	-	0.005	0.037	0.042	-
AP 1600-BROSOL 36.000 km	6	+96%	-3%	+8%	+4%	-8%	-	+13%	-53%	-45%	-
CARAVAN 4.1 L/85	2	2.1	5.05	51.25	192	3.86	-	0.009	0.058	0.067	-
140.000 km	6	-10%	0%	-13%	+2%	-9%	-	+30%	-57%	-46%	-
GOL 1.6 L/90	4	1.2	8.50	6.39	158	1.64	1.53	-	-	-	1,19
CHT/WEBER 6.600 km	3	+8%	-3%	+5%	+1%	+1%	+8%	-	-	-	-39%(-11%)**
GOL 1.6 L/90	5	2.0	8.20	20.42	145	1.82	0.87	-	-	-	1,51
CHT/BROSOL 9.800 km	2	+25%	-5%	0%	-2%	-6%	+9%	-	-	-	-54%(-27%)**
CHEVETTE 1.6L/90	2	1.45	8.7	9.90	142	1.70	1.15	-	-	-	-
WEBER 2.800 km	2	-21%	+3%	-18%	0%	-22%	+10%	-	-	-	-
MONZA 1.8 L/90	2	-	7.61	4.65	161	0.85	0.86	-	-	0.081*	-
7.000 km	2	-	-2%	-2%	0%	-7%	+16%	-	-	-48%*	-
AVERAG.VARIATION	-	+12%	-2%	-2%	0%	-10%	+12%	+22%	-55%	-46%	-46%(-19%)**

* Measured through the MBTH - spectrofotometry method
** Parenthesis indicates alcohols (methanol + ethanol)

Table 3 shows the evaporative emission data for five alcohol vehicles fueled with a blend of 60E/33M/7G and ethanol fuel and an estimate of the dayly emission increase due to the use of the blend.

In order to evaluate the practical effect of the observed increase in evaporative emission, a simple emission inventory model was developed. The model, typical of São Paulo conditions, considers that, on the average, vehicles travel 40 km/day in a three trip mode: morning, lunch time and evening driving followed by parking.

This model can then be represented by three 75 FTP urban driving cycles, three hot soak evaporative tests and two cold soak evaporative tests. The hot soak tests represent fuel evaporation after a vehicle is driven and then parked and the cold soak tests represent fuel evaporation due to fuel temperature changes during the day and the period from evening to morning.

TABLE 3 - METHANOL BLEND INFLUENCE ON FUEL EVAPORATIVE EMISSION

	HYDRATED ETHANOL (g/test)			METHANOL BLEND (g/test)			INCREASE g/day
	COLD	HOT	TOTAL	COLD	HOT	TOTAL	
ESCORT 1.6 CHT	0.67	4.09	4.76	1.66	8.08	9.74	13.95
FIAT PREMIO 1.6 - 86	0.39	4.90	5.29	2.20	27.72	29.92	74.51
CHEVETTE 1.6/90	1.12	2.75	3.87	4.14	4.72	8.86	11.95
GOL 1.6 CHT-90	0.77	1.13	1.90	3.11	2.25	5.36	8.04
MONZA 1.8/89	0.41	1.15	1.55	1.38	1.41	2.79	2.72

The analysis of tables 2 and 3 shows that:

a) the blend of 60E/33M/7G is a convenient substitute for ethanol fuel and requires no engine adjustments or conversions. Pollutant emission levels and fuel economy, on the overall, are similar when compared to ethanol results.

b) the reduction of total aldehydes and alcohol emission with blend 60E/33M/7G can be the result of an improved combustion efficiency.

c) methanol and formaldehyde emission levels are similar to emissions levels modeled by the U.S. Environmental Protection Agency for toxicologically acceptable pollutant levels in the environment (5).

d) when comparing, on a mass basis, the "daily increase" of a blend of 60E/33M/7G evaporative emissions with the observed unburned fuel emissions reduction (HC, aldehydes, alcohols) total organic emissions with the blend are about the same as with the ethanol fuel.

e) NOx emissions and fuel consumption are slightly higher with blend of 60E/33M/7G.

Considering that it is not feasible to substitute ethanol fuel by the methanol blend nationwide and that both fuels would be available simultaneously in the same regions, the need for fuel compatibility became an important issue.

Vehicle tests with 100% ethanol fuel, 75% ethanol + 25% methanol blend, 50% ethanol + 50% methanol blend, 25% ethanol + 75% methanol blend and 100% methanol blend have showun very similar results in terms of emissions, fuel economy, vehicle performance and driveability.

The fact that different fuel combinations are compatible indicates that there are acceptable tolerance ranges for the blend of 60E/33M/7G. This is shown in Fig. 1 which indicates the ideal and acceptable ranges of methanol and gasoline in the blend.

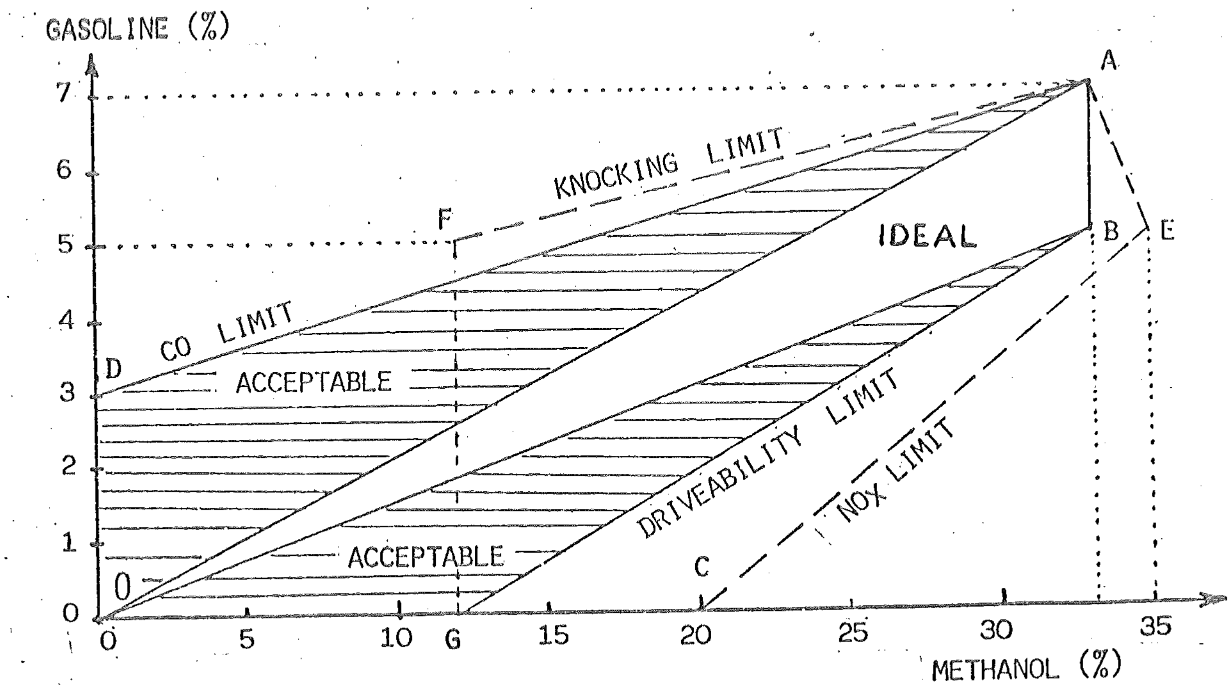

Fig. 1 - Methanol Blend Acceptable Tolerances

Thus that the ideal proportion of methanol to gasoline should be kept very close to 33/7 (line OA) as acceptable proportions are within the limits "ABGOD", defined by driveability and CO emission requirements.

In terms of materials compatibility with the blend, the first laboratory tests indicated that attack on elastomers might be a case for concern. However, after ten months of intensive use of the new blend, which averaged 200 thousand m^3/month in 1990, replacement rates of parts and components did not increases since the introduction of the blend in the market.

Public satisfaction with the new blend was also investigated. In July 1990, CETESB conducted an inquiry with 300 alcohol vehicle owners concerning the influence of the new blend on cold and hot startability, vehicle performance, fuel economy and maintenance problems (3). Results indicate good acceptance with approval rates over 80% for all items, with the exception of fuel economy, which had a 63% approval rate. Whenever the use of the blend was not ranked worse than the use of ethanol fuel, the answer was classified under the term "approval".

When considering the use of methanol in gasohol, the problem of phase separation in the presence of water must be confronted. Some field evaluations of water content in the fuels distribution system indicated that current water presence might be sufficient to cause phase separation. Since there was no time to evaluate other co-solvents that could reduce the problem, the researchers decided to recommend the use of methanol only for the alcohol vehicles.

3. OTHER ETHANOL SAVING ALTERNATIVES

As mentioned above, reduction of ethanol content in gasohol (from 22% to 12% by volume) and the addition of gasoline up to 5% by volume in ethanol fuel were the first suggested ethanol saving alternatives.

Besides their small benefit in terms of ethanol economy, both alternatives result in a negative impact on certain pollutant emissions, particularly CO and HC.

Figure 2 shows the influence of adding gasoline to ethanol fuel (a) in terms of CO and HC relative emission (a) and the effects of ethanol content in gasohol on CO and aldehyde relative emissions (b).

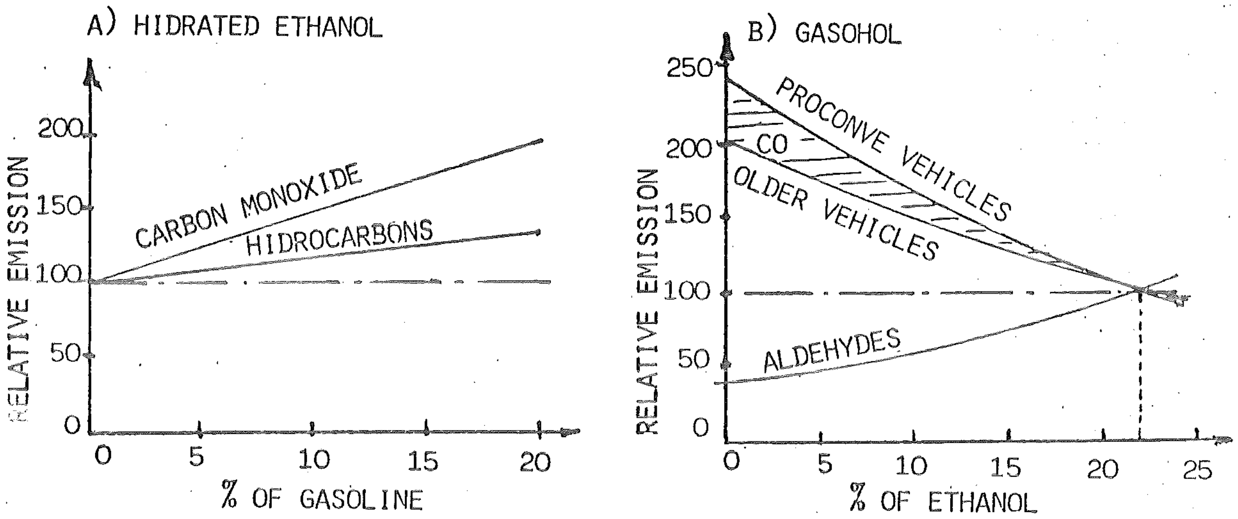

Fig. 2 - Fuels Composition Influences on Exhaust Emission

VOLKSWAGEN and FORD (6) also evaluated these alternatives and reported that the reduction of ethanol content in gasohol, from 22% to 12% results in an increase of CO and HC emissions of about 50% and 10%, respectively, and a reduction of about 20% in NOx emission. Also, the addition of 5% gasoline to ethanol fuel represents an increase in CO and HC emissions of about 25% and 10%, respectively and has no effect on NOx emissions. A more radical alternative is the use of an ethanol-free gasoline instead of gasohol. This alternative, however, results in an increase of 100% to 350% in terms of CO emission and an increase of about 40% for HC emission. The use of such an alternative results also in maintenance problems, such as rapid spark-plug carbonization, excessive gum formation in carburetors, valve rods and intake manifolds, attack on elastomer components and vapor lock problems.

These effects on emissions are caused primarily by the A/F enrichment which results from ethanol reduction in gasohol or gasoline addition to ethanol fuel.

To resolve this problem, A/F requirements must be optimized for all engine operation modes and, unfortunately, this cannot be achieved by simple engine tunning.

Another alternative which has caught some attention is alcohol engine conversion for gasohol use. In fact, the ethanol shortage has fostered the development of conversion formulas and unproven conversion kits. However, none of these conversion measures are able to give, simultaneously, great performance, good driveability, high fuel economy, attainment of emission standards and engine reliability and durability. This is because these conversion measures, in general, are inadequate and tend to offer standardized solutions to different types of engines. In addition, repair shops or engine rebuilders lack basic engine testing and tuning equipment and technical background, especially, in terms of emission control. Moreover, since the methanol blend is an emergency solution, it is highly desirable that the return to ethanol fuel use is made without the need of reconversions or tune ups.

In conclusion, based on the above mentioned effects, CETESB has been standing against these alternatives because they affect the emission control program goals, particularly in terms of CO, a major problem in a considerable number of Brazilian cities.

4. METHANOL USE AND AIR POLLUTION

In terms of air pollution, the use of methanol could result in unacceptable public exposure to methanol and formaldehyde. To address this question CETESB established a monitoring program for ambient concentrations of methanol, ethanol, formaldehyde and acetaldehyde, in addition to the routine monitoring of CO, photochemical oxidants (expressed as ozone - O_3), and other common air pollutants.

The monitoring program (7) evaluated air quality from March through September 1990 in two monitoring stations, in the City of São Paulo. The Cerqueira Cesar station is directly affected by heavy traffic while the Mooca station, though located in an area of dense traffic, is less affected by direct emissions due to the distance from the traffic ways. The reported data shows that methanol was detected in only 12,8% of the 86 samples collected at the Cerqueira Cesar station. At the Mooca station methanol was not detected in any of the 24 samples. The detection limit of the gas chromatography analytical procedure used for methanol is 0.15 ppm. The highest methanol recorded value was 0.47 ppm at Cerqueira Cesar.

Formaldehyde concentrations were detected in all of the 50 Cerqueira Cesar samples and 12 Mooca samples. The highest values recorded for formaldehyde were 32 ppb and 17 ppb at Cerqueira César and Mooca, respectively. Only 14.0% of formaldehyde results were higher than 24 ppb.

According to Hervey et alii (5), ambient concentrations lower than 3.44 ppm for methanol and 24 ppb for formaldehyde are below the range of concern from a toxicological point of view. These values represent the lower limit of the range and are not believed to result in adverse physiological effects. For methanol, CETESB's results indicate that concentrations are about one tenth of the lower limit of the range. For formaldehyde, 86% of the recorded values are below this limit. The remaining 14% are still below 120 ppb, which was defined by Harvey et alii as the intermediate limit of the range of concern and it is believed to have a more solid basis for concern than the lower limit.

Despite of the measured peak of 32 ppb, previous monitoring work has shown that formaldehyde concentrations usually reach considerable levels in São Paulo. For instance, in 1986, a peak of 59 ppb was measured at a downtown location (Praça do Correio) and no methanol blend was in use at that time. Therefore, it is safe to say that the use of methanol has not contributed to an increase in formaldehyde concentrations in the City of São Paulo.

In terms of the other pollutants which are routinely monitored, the use of the blend has not resulted in any negative effects on air quality.

The environmental importance of blend use is that it saves a considerable amount of ethanol and it does not increase pollution from alcohol vehicles. The economy of ethanol means availability of anhydrous ethanol which has to be added to gasoline, in 22% by volume, to obtain gasohol and therefore to fulfill the A/F requirements of the gasohol vehicles. Consequently, emissions from gasohol vehicles are also not increased. As it can be seen, the blend has become a key factor for the Motor Vehicle Pollution Control Program.

When discussing the safety aspects related to the blend use, it is worthy of note that the presence of gasoline in the blend inhibits ingestion (which is the major cause of methanol acute intoxication), because the blend acquires the distinctive odor and taste of gasoline.

Another point of interest is that ethanol is a known "antidote" in case of methanol poisoning because it greatly slows methanol's entrance into its metabolic pathway (8). Considering all possible ways of body intake (ingestion, skin absorption or inhalation) ethanol will be always associated to methanol, in at least a 2:1 ratio. Therefore, it is possible to infer that the risk of public exposure to methanol is lowered by the presence of ethanol.

Furthermore, for ease of recognition, the blend received a red dye which gives the fuel a pinky color, therefore differentiating the blend from other fuels.

5. CONCLUSIONS

Despite the present ethanol shortage in Brazil, there are viable alternatives to overcome the crisis.
Reducing the ethanol content in gasohol or adding gasoline to ethanol fuel helps to save ethanol, however, these alternatives can cause engine malfunction and result in significant effects on vehicle emissions, particularly, an increase in carbon monoxide and hydrocarbons. Other alternatives such as alcohol engines

conversion to gasohol are not recommended due to the impact that uncontrolled conversions can have on air quality and on engine performance and reliability.

The best known alternative, in terms of air pollution control, fuel supply and fuel quality guarantee is the use of a blend of 60E/33M/7G. It is an alternative which gives great flexibility to the management and recovery of the National Alcohol Program and simultaneously, does not put the National Motor Vehicle Pollution Control Program at risk.

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