Middle East Research Journal of Engineering and Technology
ISSN **2789-7737 (**Print) | Open Access
Frequency: Bi-Monthly
DOI: 10.36348/merjet.2021.v01i01.001

Website: http://www.kspublisher.com/
Email: office.kspublisher@gmail.com

Analysis of Onset of Transition Region on a Supersonic Wing

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ABSTRACT: Climate change is due to the sole effect of global warming, which is an outcome of Green House Gas (GHG) emissions. The aviation industry is considered to be one of the fastest-growing sources of these emissions. Mitigation of these emissions is a challenging task since it requires the entire world to work hand-in-hand. The International Civil Aviation Organisation (ICAO), an international governing body, has come up with a challenging target of net 50% reduction in global aviation emission by 2050, relative to the emission levels in 2005. To achieve this target, there must at least be 2% improvement in fuel efficiency every year. This 2% efficiency improvement is further split into Aircraft technology improvement (1.1%) and Airport infrastructure improvement (0.9%). This research aims to achieve the 2% improvement by aircraft technology improvement. Over the years, it was evidenced that mitigation of skin-friction drag on the wing would contribute to a majority of the fuel efficiency improvement. Hence, the primary aim is narrowed down to wing skin friction drag. The theory of boundary-layer has been studied thoroughly in this research work. Also, the interaction between the shock-waves and boundary-layer will be briefed in this paper as the baseline aircraft is supersonic. As it was understood as understood over the research that extension of the laminar boundary-layer favours the reduction of skin-friction drag, it is the primary objective of this research work. A Computational Fluid Dynamics (CFD) study on the of the wing aerodynamics has been conducted to enhance the performance of the aircraft and ANSYS Fluent has been used to serve this purpose. The results obtained from ANSYS fluent will be validated in one of the NASA's open-source tool VSPAero which uses Vortex Lattice Method to model the flow. Turbulent Kinetic Energy technique is used to predict the onset of the transition of the flow. Initial study is performed on the 2D aerofoil and one the most optimum aerofoil is obtained, the study is continued in 3D to understand the effect of cross-flow instabilities. Free-stream velocity profile variation is another reliable technique in predicting the transition and will be discussed in the next volume of the paper. Finally, aerodynamic performance analysis will be performed to obtain the best wing configuration.

Keywords: Aerodynamics, Supersonic, Boundary-layer, Turbulent Kinetic Energy, Concorde, E19 Aeolus, Compound delta wing, CFD, ANSYS Fluent, VSPAero, OpenVSP.

RESEARCH PAPER

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How to cite this paper:
Mohamed H. Buzgeia *et al.;* "Study of the Metals Content of Local and Imported Bottled Drinking Water in Benghazi and Their Compliance with the Libyan Specifications for Bottled Drinking Water". Middle East Res J. Eng. Technol, 2021 Nov-Dec 1(1): 1-6.

Article History:
| Submit: 11.11.2021 |
| Revised: -- |
| Accepted: 27.11.2021 |
| Published: 20.12.2021 |

INTRODUCTION

Nowadays, the quality of goods and services is the main element in the competition between production corporations in the local regions and international markets. It becomes more important when talking about strategic commodities of great importance, such as the production of bottled drinking water. The nature of drinking water standards varies across countries and regions. There are no unique globally applied standards. It is necessary to develop and implement standards, taking into account existing laws, community health and local governance, and assess the capacity to develop and enforce regulations. Heavy metals are among the most intensively studied pollutants in water samples around the world. Metals are a group of elements with atomic weights ranging from 63.549 to 200,590 [1-3].

Metals are characterized by a similar electronic distribution in the outer shell, such as copper, cadmium, and zinc. Metals can be divided into two groups: transition metals and metal-like elements. The transition metals include manganese, iron, copper, and cobalt. This group is essential for metabolism at low concentration levels but can become toxic at high concentration levels. The metal-like elements include arsenic, cadmium, lead, mercury, selenium, and tin. This group is not important for metabolic function. This group also becomes toxic at low concentration levels. Some minerals have benefits for the human body as they build cells and help in vital reactions in the body. The danger of heavy metals comes from their bioaccumulation in the human body faster than degradation by metabolism or excretion [4-6]. Mercury, for example, is a shiny silver metal that is liquid at room temperature and freezes at -39°C, its atomic number is 60 and the atomic weight is 200. It is toxic to both humans and aquatic organisms. It has now become widespread and has a specific density of 13.5. Like other highly toxic metals, it gathers in the bodies of living organisms and remains for a long time. It acts as a cumulative poison and is used in many industrial processes. Mercury salts are very toxic. The levels of mercury in treated drinking water are usually low due to the use of chemicals nurturing. Mercury levels in water sources are less than 0.0002 mg/L, which is reduced to less than these levels during water treatment. The United States Environmental Agency has suggested 0.002 mg/L as a level of mercury compounds in water [7]. Lead comes after mercury in terms of its danger to the environment. The concentration of lead in treated water increases, especially when the water hardness decreases or the pH decreases. On the basis of consumption, the daily intake of lead ranges from 0.02 to 1 mg/L based on all lead consumption. The largest source of lead in general is food. However, lead levels can be much higher in Industrial work areas than the general environment levels. Lead affects formation of blood, nervous system, kidneys, heart, and reproductive system. The American Environmental Agency sets the maximum level of lead contamination at 0.005 mg/L of water. On the other hand, the World Health Organization has suggested a ratio of 0.05 mg / litter as accepted level [8]. Regarding cadmium, it is a rare metal, its color is silvery white, soft, and it conducts heat and electricity. Cadmium has an atomic number of 4.8, atomic weight of 112, and a specific gravity of 8.65. It oxidizes easily in wet atmosphere. Cadmium is considered a heavy metal. It is harmful to health; as it is easily absorbed by the respiratory and digestive systems. It accumulates in the kidneys and liver. Cadmium pollution affects the representation of calcium in the body, which results in osteomalacia. Cadmium levels are usually very low in water supply. There are only very small amounts of cadmium in raw water supply; and in if the levels are slightly raised, a lot of cadmium is removed during treatment. Furthermore, drinking water usually contains a very low concentration of cadmium, even if well water It contains high concentrations of cadmium. World Health Organization sates that the weekly intake of cadmium should not exceed 0.5 milligrams per person. Regarding zinc, it has an atomic number of 28 and a density of 8.902 g/cm3. It is a silvery, odourless metal [7, 8]. Zinc compounds are widely spread in nature, including calamine and zensite. Zinc is one of the essential elements for life, and it is present in all cells of the body. Zinc affects the rate of growth, bone development, skin integrity and the growth and functioning of the reproductive system. Zinc does not accumulate in tissues. Zinc can be considered as non-toxic. Zinc gives water an unpleasant astringent taste. It adds opacity to water containing more than 5 mg/l. It forms a buoyant layer during water boiling. The indicative value of zinc in drinking water was determined as 5 mg/L [9]. Chrome is a gray metal, ranging in color from blue to white. It is an odourless element. It does not dissolve in water and oxidizes under strong oxidation conditions to hexachromium. Chromium generally causes upper respiratory tract irritation and severe nasal irritation. It is found in nature in the form of trivalent chromium, which is the least toxic form. In the sea water, chromium is often found in the form of hexavalent chromium, which may be reduced to triple chromium equivalence by organic matters in water and deposited on the sea floor. The levels of chromium found in water are generally low due to its low solubility in water. High levels of chromium occur in water with high hardness. Total chromium levels in water reached to 10 mg/L. The treated water is usually less in its chromium content than raw water. The chromium content of drinking water is 10 mg/l [8]. Copper is one of the oldest heavy metals known on Earth. The copper concentration in treated water can be higher than in raw water due to copper corrosion. Copper compounds dissolved in water leading to unpalatable color and taste in drinking water. The taste can be observed in distilled water at a concentration of 2.6 mg/L. Copper concentrations greater than 1 mg/L causes blue color in adjacent bodies, and this is the value recommended in drinking water standards. Regarding arsenic, it is found naturally in all environments. It is usually found in the form of compounds combined with sulphur, copper, cobalt, lead and zinc. Arsenic may be present in water streams as a result of erosion in surface rocks [6, 7]. The chemical form of arsenic affects its absorption. Arsenic is absorbed at a very low rate, while trivalent and pentavalent inorganic arsenic compounds are easily absorbed. There is no conclusive evidence that arsenic in any of its chemical forms is necessary for humans, although some of its compounds are useful for animal growth. The accumulated amount of arsenic in the body depends on its chemical and physical forms, the entrance way, the dose, the duration of exposure, the age and sex of the exposed individual. Inorganic arsenic is more toxic than organic arsenic. Trivalent inorganic arsenic is more toxic than pentavalent. It is recommended that when water contains arsenic at levels of 0.05 mg / litter, it should not be trivalent arsenic. Trivalent arsenic can greatly weaken human systems. This weakness can occur at a concentration of 0.2 mg / liter of drinking water. Doses of 70-180 mg/L lead to death, and high occupational exposure causes lung cancer. Maximum arsenic limits in the standard specification for bottled drinking water is 0.01 mg/L. Iron is very important element in human life [5, 6]. Iron contamination is rare. The presence of iron in well water is due to the presence of ferric salts in soils and groundwater in insoluble form. Ferric salts are reduced from insoluble carbonates and oxides to water-soluble ferrous salts as a result of the reaction of carbon dioxide with ferric salts. The concentrations of ferrous iron in groundwater range from 0.1 mg/L to more than 30 mg/L. The dissolved ferrous compounds are colour less, and when the groundwater is exposed to the atmospheric air, the ferrous salts oxidize to the un-dissolved ferric salts. The un-dissolved ferric salts in the water forms gelatinous substance and give the water a brick red colour. Iron is removed from well water, by aeration oxidation such as chlorine. Standards and specifications of bottled drinking water set iron up to a maximum limit of 0.3 mg/L. Table 1 shows the indicative specifications and standards for minerals as the maximum allowed by local and international agenise [7-9].

Table 1: Local and International Specifications of Metals in Drinking water

Metal	World Health Organisation Standards mg/L	Libyan Specifications mg/L
Copper	1	1
Iron	0.3	0.3
Zinc	5	3
Arsenic	0.05	0.01
Mercury	0.001	0.001
Cadmium	0.005	0.003
Chrome	0.05	0.05
Lead	0.05	0.01

Several studies have assessed the quality of bottled drinking water in Libya and some Arab countries. A study on the quality of bottled drinking water in the city of Misrata in Libya during 2018; the study included 12 water factories. This study assessed the levels of arsenic, copper, cadmium, mercury, and zinc. It was found that zinc and copper have high results, but they did not exceed the maximum allowed limits in the Libyan and international specifications. It was noted that the arsenic is the only element whose results were lower than the allowed limits in all samples. On the contrary, mercury and cadmium in all sample exceeded the maximum allowed limits in the Libyan and international specifications [10]. In Kuwait, 25 types of bottled water were examined. All varieties were conforms to the local specifications of Kuwait. The results showed that the concentration of some minerals in some types of bottled water was higher than that in pine water. However, the quality of all items was in compliance with the World Health Organization standards for bottled drinking water [11]. In Kingdom of Saudi Arabia, a study assessed the properties and quality of bottled drinking water. The measurements showed that all metals concentrations conformed to the Saudi specifications. Another study was carried in Kingdom of Saudi Arabia. The study concluded that all metals measured parameters were confirmed to the Saudi Arabian Standards [12, 13]. In Iraq, a study of mineral drinking water properties was conducted in city of Tikrit during 2016. The results of the study showed that the levels of metals of the studied samples were in conformity with the local and international standards for drinking water. In Iraq another study was also conducted on some physical, and chemical properties of the locally and imported bottled water in the city of Baghdad. The results showed high values of magnesium in locally bottled water samples compared to imported samples. Also in Iraq during 2009, a study of the metals in ten types of bottled water was carried out. The results showed that both local and imported water conformed to local and international specifications [14, 15]. In Sudan, a study conducted during 2017 on the chemical properties including metals. The results showed that all metals were conformed to the Sudanese Standards [16]. The current research paper aims to evaluate the minerals content of ten types of bottled water (six local brands, four imported ones) that marketed in city of Benghazi. The study also aims to compare the results with the local Libyan specifications for bottled drinking water.

MATERIALS AND RESEARCH METHODS

This study was conducted in the city of Benghazi; the second largest Libyan city during 2020-2021. Samples of bottled drinking water were collected and analysed. The analysis includes the physical, chemical and microbiological properties. The scope of this paper includes the metals content. The study was conducted on six types of locally bottled drinking water Al-aen Al Aseel - Al Nafoura - Pure - Shahd - Al Reem. Another four imported bottled drinking water brands were included in the study as shown in Table 2. The samples taken are sufficient to complete the required analysis; the samples were numbered, well diagnosed, and examined immediately after taking them. The tests were conducted in the laboratory of the Food and Drug Control Center, Benghazi as well as the Laboratories of Faculty of Public Health, University of Benghazi.

Table 2: Distribution of samples by type and size Origin and method of sterilization

Symbol	Product Names	Size	Origin	Sterilization
A	Al-aen	500 ml	Libya	Ozone and UV rays
B	Al Aseel	500 ml	Libya	Ozone and UV rays
C	- Al Nafoura	500 ml	Libya	Ozone and UV rays
D	Pure	500 ml	Libya	Ozone and UV rays
E	Shahd	500 ml	Libya	Ozone and UV rays
F	Al- Reem	500 ml	Libya	Ozone and UV rays
1	Flow	500ml	Egypt	Ozone and UV rays
2	Nova	660 ml	Saudi Arabia King Dom	Ozone and UV rays
3	Pinal ELM	330ml	Turkey	Ozone and UV rays
4	Spring	500 ml	United King Dom	Ozone

Determination of Metal Concentration

To avoid contamination of the sample from external sources, all used tools and glassware were flooded in 20% nitric acid solution for 24 hours, washed with distilled water, then washed with deionised water. Copper, iron, zinc, and arsenic were determined by atomic absorption method using Flame Atomic Absorption Spectrophotometry. Operational conditions are shown in Table 3 [17].

Table 3: Operational conditions of Flame Atomic Absorption Spectrophotometry

Requirements	Cupper	Iron	Zinc	Arsenic
Lamp Current	4 MA	4 MA	4 MA	4 MA
Fuel	Acetylene	Acetylene	Acetylene	Acetylene
Support	Air	Air	Air	Air
Wave length	324.7 nm	248.3 nm	213.9 nm	213.9 nm
Slit length	0.5 nm	0.2 nm	1 nm	1nm

Determination of mercury, cadmium, chrome, and lead were determined by atomic absorption method; GTA 120 Graphite Tube Atomizer. Operational conditions are shown in Table 4. Descriptive and analytical statistics of all samples and results were generated by SPSS [18].

Table 4: Operational conditions of Graphite Atomic Absorption Spectrophotometry

Requirements	Mercury	Cadmium	Chrome	Lead
Lamp Current	4 MA	4 MA	7 MA	5 MA
Spectral Bandwidth	0.5 nm	0.5 nm	0.2 nm	0.5 nm
Maximum Absorbance	0.35	0.7	2	1.4
Wave length	253.7 nm	228.8 nm	357.9 nm	283.8 nm
Maximum Ash Temperature	500 C^0	300 C^0	1100 C^0	600 C^0

RESULTS

The results of the minerals contents conducted on locally manufactured bottled drinking water samples and imported bottled drinking water samples are shown in table 5. It is clear from the results that the average value of copper is 0.0106 parts per million, and for iron is 0.067 parts per million. All samples of zinc are less than 0.003 ppm, and arsenic is less than 0.01 ppm. The average value of the element copper is 0.065 parts per million, iron 0.05 ppm and all samples for zinc concentration is less than 0.003 ppm; while arsenic concentration is less than 0.01ppm. The results of the determination of heavy metals mercury, cadmium, chromium and lead for water samples are showed in table 5. All samples contained less than 0.003 parts per million, and less than 0.001 parts per million for elemental cadmium and mercury, respectively. The elements chromium and lead are both less than 0.005 parts per million. The results of the concentration of mercury, cadmium, chromium, and lead for imported bottled drinking water samples showed that they were all less than 0.001, 0.003, 0.005, and 0.005 ppm for mercury, cadmium, chromium and lead respectively.

Table 5

Sample	Cupper	Iron	Zinc	Arsenic	Mercury	Cadmium	Chrome	Lead
A	0.119	0.084	< 0.003	<0.01	<0.001	<0.003	<0.05	<0.005
B	0.139	0.072	< 0.003	<0.01	<0.001	<0.003	<0.05	<0.005
C	0.107	0.046	< 0.003	<0.01	<0.001	<0.003	<0.05	<0.005
D	0.123	0.056	< 0.003	<0.01	<0.001	<0.003	<0.05	<0.005
E	0.099	0.046	< 0.003	<0.01	<0.001	<0.003	<0.05	<0.005
F	0.049	0.1	< 0.003	<0.01	<0.001	<0.003	<0.05	<0.005
Mean	0.106	0.067	~ 0	~ 0	~ 0	~ 0	~ 0	<0.005
1	0.110	0.082	< 0.003	<0.01	<0.001	<0.003	<0.05	<0.005
2	0.05	0.01	< 0.003	<0.01	<0.001	<0.003	<0.05	<0.005
3	0.05	0.038	< 0.003	<0.01	<0.001	<0.003	<0.05	<0.005
4	0.05	0.07	< 0.003	<0.01	<0.001	<0.003	<0.05	<0.005
Mean $\pm$ SD	0.065	0.05	~ 0	~ 0	~0	~0	~0	~0

DISCUSSION

From the results obtained for locally manufactured drinking water samples, it was found that the concentration of copper for locally manufactured bottled drinking water ranged from 0.049 to 0.139 ppm with an average of 0.106 ppm. The concentration of zinc element ranged from 0.046 to 0.084 parts per million, with an average of 0.067 parts per million. The results of zinc and arsenic for all samples showed less than 0.003 ppm, and less than 0.01 ppm respectively. Through these results, it was found that the concentrations of these elements did not exceed the permissible limit in the Libyan Standard Specification No. 10 of 2008. The results showed that the concentration of the copper element ranged between 0.05 - 0.11 parts per million, with an average of 0.065 parts per million. Iron levels ranged between 0.01 - 0.083 parts per million with an average of 0.05 ppm for imported bottled drinking water samples. Accordingly, all the obtained results did not exceed the permissible limit in the Libyan Standard Specification No. 10 of 2008. These results are in agreement with the results of the study of some evidence on the quality of bottled drinking water in the city of Misurata, Libya. The current study agrees with Misurata city's study in terms of copper, zinc, arsenic, and they differ in Iron levels. The study also agreed with a study that was conducted in the city of Riyadh in Saudi Arabia on the quality of domestic and imported drinking water. Moreover, the current study agrees with a study of some physicochemical and microbial properties of bottled water locally produced and imported in the city of Baghdad. Through the results obtained in table 5, it was shown that the concentration of mercury for all samples was less than 0.001 ppm, and the cadmium concentration was lower than 0.003 parts per million, while the concentration of chromium and lead for all Samples are less than 0.005 ppm. By comparing the results with the Libyan standards, it was concluded that the current results conform to the standard. The results shown in table 5 showed the concentration of chromium and lead, which were for all imported samples are less than 0.005 ppm. Cadmium and mercury concentrations for all imported samples are less than 0.003ppm, 0.001ppm respectively. All obtained results are not exceeding the permissible limit of the Libyan Standard.

CONCLUSION

The studied local bottled drinking water brands in Benghazi and the imported ones from Egypt, Saudi Arabia, Turkey, and the United Kingdom achieved a good level of quality in all measured metals properties comparing to the Libyan standard specification for bottled drinking water.

CONSENT

As per international standard or corresponding universities standards, factories consent has been collected and preserved by the researchers.

ACKNOWLEDGEMENTS

Authors are grateful to all factories who participated in the study.

Competing Interests

Authors have declared that no competing interests exist.

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