COMPARATIVE STUDY OF THE ACTIVATED CARBONS: PART-II: LINEAR RANKING MODEL

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ABSTRACT

Two codes of Bureau of Indian Standards, viz., IS 2752:1995 and IS 8366:1989 are available for classification of adsorbents for their use in specific purposes based on their physico-chemical characteristics. No IS code is available for directly assessing the suitability of activated carbon for contaminated water treatment. Two specific categories of activated carbons prescribed in the above IS codes are considered in the present study, representing the activated carbons suitable for contaminated water treatment. Literature review showed that most of the data for the characteristics prescribed by the two specific categories of activated carbons listed in the above two IS codes is missing. In such cases, classification of activated carbon for a particular purpose becomes difficult. A ***four scale linear ranking model*** *is developed in this study for the systematic assessment of the suitability of activated carbon for a specific purpose and is illustrated with a data source where the information pertaining to the relevant physico-chemical characteristics is fully available. It is concluded from the present study that, (i) it is possible to rank the activated carbon based on its physico-chemical characteristics and (ii) there is a further scope in the improvement of the proposed ranking model.*

Key words: *Activated carbon, Linear Ranking model, Adsorption, Physico-chemical characteristics, Bureau of Indian Standards.*

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INTRODUCTION

A number of low cost novel adsorbents are being developed by several investigators in pursuit of an alternative to the costlier commercial activated carbon (De and De, 1994; Rai et. al. 1998; Rao et al., 1999, Rao et al., 2000; Babu and Ramakrishna, 2002) to be used for the treatment of a number of pollutants from contaminated water. The developed novel adsorbents are being examined and reported for a wide range of physico-chemical characteristics (Babu and Ramakrishna, 2002). Two codes of Bureau of Indian Standards (BIS), viz., IS 2752:1995 (originally published in 1963 and revised in 1978, 1989, and 1995) and IS 8366:1989 (originally published in 1977 and revised in 1989) are available for classification of adsorbents for their use in specific purposes based on their physico-chemical characteristics. IS 2752:1995 defines the activated carbon for two specific purposes viz.,

- Respirator carbons and Solvent recovery (Type-1)
- Water treatment (Type-2)

IS 8366:1989 defines the activated carbon for three specific purposes viz.,

- Decolorizing vegetable oils, fats, and waxes (Type-1)
- Decolorizing sugar solutions, corn sugar solutions etc. (Type-2)
- Decolorizing pharmaceuticals (Type-3)

It can be noted from the above information that, both the above IS codes are not suitable for directly classifying the adsorbents for wastewater treatment. A close examination of the information under the above categories revealed (Babu and Ramakrishna, 2002) that two specific categories, viz., Type-2 of IS 2752:1995 and Type-3 of IS 8366:1989 can be approximated to those dealing with the suitability of activated carbons for contaminated water treatment. Of the above two types, Type-2 of IS 2752:1995 deals with activated carbons suitable for water treatment. Type-3 of IS 8366:1989 deals with the activated carbons suitable for decolorization of pharmaceuticals. The wastewater from pharmaceuticals causes pollution and needs to be treated. Decolorization of pharmaceuticals can be considered as a treatment option.

The investigators are however not reporting some of the physico-chemical characteristics of the adsorbents they have developed in accordance with any of the above two categories of IS codes. Babu and Ramakrishna (2002) studied in detail the anomalies in reporting the physico-chemical characteristics of the adsorbents *vis-à-vis* the prescribed characteristics. In fact, there are no specific guidelines available to assess the suitability of the novel adsorbent for contaminated water treatment. Babu and Ramakrishna (2002) have stressed the need to develop a new IS code for such purposes. The authors also mentioned that the physico-chemical characteristics of commercial activated carbon reported in the literature are varying indicating that no specific set of guidelines are available to develop a commercial activated carbon with uniform characteristics. In view of the above circumstances, assessment of the suitability of the novel adsorbent (or even commercial activated carbon) for contaminated water treatment becomes the necessity. When an activated carbon is prepared from standard or indigenous methods, it is necessary to identify its suitability for a specific purpose. A systematic assessment of the activated carbon will help in solving such problems. In order to identify a systematic methodology, the development of a ranking model is explored for defining suitability of the activated carbons for a specific purpose where information is fully available for the relevant characteristics.

The linear ranking model is developed for the data available in the literature (Rengaraj et al., 1999) to rank the activated carbons for their suitability for contaminated water treatment based on the compliance of their characteristics prescribed under the two IS codes mentioned earlier. It is found that, the results are interesting and there is a further scope for improvement in the developed ranking model.

Linear ranking model

Rengaraj et al., (1999) prepared six different activated carbons viz., Rubber Seed Carbon (RSCC), Polyseed Carbon (POSCC), Myrobalan Carbon (MWC), Cashewnut Sheath Carbon (CSC), Palm Tree Flower Carbon (PTFC), and Pongam Seed Carbon (POSCC) using six standard procedures of preparing activated carbon viz., Acid process, Sulphate process, Carbonate process, Chloride process, Dolomite process, and Pyrolytic process from the respective agricultural wastes. They examined selected characteristics of the activated carbon. A sample of Commercial Activated Carbon (CAC) is also subjected to similar tests for comparison. For the present study, the available information is compiled for each of the above activated carbons. The details of characteristics are compared with their permissible limits prescribed under IS 2752:1995 and IS 8366:1989. The frequency of the specific activated carbon complying with the permissible limits is determined. The maximum possibility of compliance for each of the activated carbon is six times for each of the characteristics since there are six different methods of preparation. So, there will be a maximum of 36 & 18 possible chances of compliance for the activated carbons prepared from agricultural wastes under IS 8366:1989 and IS 2752:1995 respectively. The CAC however has only one maximum possible chance of compliance for each of the characteristics. The number of times (frequency) the activated carbon complying with the prescribed limits is examined and recorded. The percentage of compliance is calculated with respect to the frequency of compliance for the prescribed limits and the maximum possible chances of compliance of the material. The results are summarized in Tables- 1 & 2.

Table-1

Table-2

It is evident from Tables- 1 & 2 that, the activated carbons prepared from agricultural wastes, are not fully complying with the guidelines prescribed under IS 2752-1995 and IS 8366-1989. A model is proposed for the **relative ranking** of the activated carbons under study based on the frequency of their complying with the standards. Four ranks are proposed viz., Very Good, Good, Fair and Poor. They are **linearly distributed** with regard to percentage compliance and are given in Table-3.

Table-3

Based on the above scale of ranking, Tables- 1 & 2 reveal that, the CAC and all the six activated carbons tested are more suitable (**Good to Fair**) for decolourization of pharmaceuticals than for water treatment (**Fair to Poor**). The CSC is ranked **Poor** as it has a compliance of only 22.22%. The above ranking model can be modified by increasing the levels of scale of ranking and can be used to assess the relative suitability of the activated carbons. The model developed help in a **systematic assessment** of the suitability/classification of an activated carbon for a specific purpose and can be applied where information is fully available for the relevant characteristics.

It should be noted that, the percentage compliance under IS 8366:1989 for all the six activated carbons prepared by Rengaraj et al. (1999), is higher than that for CAC (see Table-1). RSCC, PSCC, and MWC recorded a percentage compliance of more than 50% to that recorded by the CAC (33.33%). However, the percentage compliance of the above six activated carbons under IS 2752:1995 is almost same as that for CAC. The percentage compliance for CSC is less than that for CAC at 22.22%. The CAC is expected to have much better compliance than that is recorded (33.33% under both the

IS codes). The surface area, for example, of CAC is very low (296 m^2/g) than that prescribed (minimum: 550 m^2/g) by IS 2752:1995. The range of the surface area of activated carbon prepared using the six different methods (Rengaraj et al., 1999) is better than for CAC for at least three out of six materials. At the same time, the surface area of CAC (296 m^2/g) is lesser than the minimum surface area (486 m^2/g) and far lesser than the maximum surface area (1298 m^2/g) of CAC reported in literature and used in the compliance studies (Babu and Ramakrishna, 2002). The above observations lead to the fact that, the CAC reported by Rengaraj et al., (1999) and that used in the compliance studies are different and their method of preparation could also be different. Interestingly, all the above activated carbons are commercially available. Based on this information, it can be concluded that a need is arising to have a standard and common method of activated carbon preparation, **at least** for the grade that is commercially available.

In the present study, a **linear ranking model** with four scales of ranking is initially proposed for the relative ranking of activated carbons based on their characteristics. This model can be improved by studying the significance of each of the characteristics with reference to the objective of the usage of the activated carbon and accordingly awarding relative weightage(s). In order to accomplish this task, the existing IS codes are also to be modified as mentioned in the earlier part of the present study. A large database pertaining to complete information of the physico-chemical characteristics for each activated carbon used by the investigators is essential. However, there is a lot of scope in the systematic development of a ranking model for the suitability of activated carbon for a specific purpose.

SUMMARY AND CONCLUSIONS

It is found from literature that the activated carbon prepared from various raw materials are being examined and reported for more characteristics than prescribed under the relevant IS codes. However, some of the characteristics prescribed by the IS codes are not being examined by the investigators. The authors have done an extensive study for the anomalies observed while reporting the characteristics of adsorbents in the literature and are documented in the Part-I of this study. In addition to the above, the authors have suggested that (i) there is a need to re-examine the characteristics selected and prescribed under IS 2752:1995 and IS 8366:1989, and (ii) a separate IS code is desirable for defining the suitability of activated carbon for wastewater treatment.

In the light of above observations, it is felt that as of now, there is no specific tool or guideline available for assessing the suitability of activated carbon as an adsorbent for wastewater treatment. As an alternate solution to the above problem, a four scale linear ranking model is developed for the systematic assessment of the suitability of activated carbon for a specific purpose and is illustrated with a data source where the information pertaining to the relevant physico-chemical characteristics is fully available. The data is compared with the above-mentioned two IS codes. The six activated carbons tested and CAC (used for comparison) are more suitable (**Good to Fair**) for decolourization of pharmaceuticals than for water treatment (**Fair to Poor**).

The conclusions of the study are as follows:

- The ranking model proposed in the present study based on a specific case study substantiates that it is possible to rank the activated carbon based on its physico-chemical characteristics.
- There is a further scope in the improvement of the proposed ranking model.

LIST OF TABLES

Table-1 Comparison of activated carbon characteristics in compliance with IS 8366:1989

Table-2 Comparison of activated carbon characteristics in compliance with IS 2752:1995

Table-3 Proposed ranks under Linear Ranking Model

Table-3 Proposed ranks under Linear Ranking Model

S. No.	Range of percentage compliance	Rank
1	≥ 75	Very Good
2	50 – 74	Good
3	25 – 49	Fair
4	< 25	Poor

Table-2 Comparison of activated carbon characteristics in compliance with IS 2752:1995

Characteristic	RSCC	PSCC	MWC	CSC	PTFC	POSCC	CAC
Moisture content, %	0	0	0	0	0	0	0
Ash content, %	6	6	6	4	6	6	1
Surface area, m^2/g	1	1	0	0	0	0	0
Total	7	7	6	4	6	6	1
Complying, %	38.89	38.89	33.33	22.22	33.33	33.33	33.33

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Table-1 Comparison of activated carbon characteristics in compliance with IS 8366:1989

Characteristic	RSCC	PSCC	MWC	CSC	PTFC	POSCC	CAC
Moisture content, %	6	4	6	6	6	5	1
Ash content, %	6	6	6	6	6	6	1
Matter soluble in water, %	2	4	1	1	0	0	0
Matter soluble in acid, %	5	5	4	2	1	2	0
pH	1	0	1	0	0	0	0
Decolorizing power	0	0	0	0	0	0	0
Total	20	19	18	15	13	13	2
Complying, %	55.5	52.78	50	41.67	36.1	36.1	33.33