Treatment of remnant dye solutions in analytical, educational and small research laboratories with recyclable silica gel

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Keywords: **dyes, stains, wastewater from educational laboratories, silica gel, adsorption, recycling, water treatment**

Abstract: Silica gel was used as adsorbent for dyes in aq. solutions. Afterwards, the silica gel with the adsorbed dye was heated to 600 °C, at which the dye combusted leaving behind clean silica gel. This silica gel can be reused in the adsorption process. The operation leaves behind little waste products. It is an optimal procedure for educational and research laboratories which are working with biological stains, food colorants and some non-commercial dyes.

Introduction: Dyes are used in analytical and educational as well as research laboratories as pH indicators, titration end-point indicators, stains for biological preparations as well as demonstration object to understand color, UV-VIS (absorption) spectroscopy, adsorption phenomena, dye-stuff for the textile in the industry in an educational context. Dyes as chemicals are already used in high school laboratories across the United Arab Emirates.

As the dyes are often used in aqueous solutions (solutions in water), they are discarded after use into the sink, where they mix with the municipal wastewater. Although the dyes are present in the waste in small concentrations (usually at 10 parts per million to 100 parts per million [ppm]), the wastewater clearly is colored which leads to an optical pollution of the wastewater. It must be said that certain dyes at high concentrations lead to bad health effects, if persons are exposed to them on a continuous basis. Very severe cases of excessive exposure to coloured effluents can make humans more vulnerable to immune suppression, respiratory and circulatory diseases, and disorders of central nervous system, including neurobehavioral disorders. Also, a link of exposure to dye wastes and the occurrence of allergies, autoimmune diseases and eye or skin infections has been found in a limited number of cases.

Therefore, it is appropriate to treat dye-loaded solutions before discarding them into the sink. In schools or at universities, the treatment of such solutions before discarding them also has an educational effect to “save our environment”.

In the following, a simple procedure is shown with which dye loaded waste water can be treated. The procedure needs a magnetic stirrer and an oven that can reach 600 °C as main instruments and as the main investments involved. Additionally, glass beakers, a glass funnel, filter paper (or a glass fritte with a suction flask), a crucible and a magnetic stirring bar are needed.

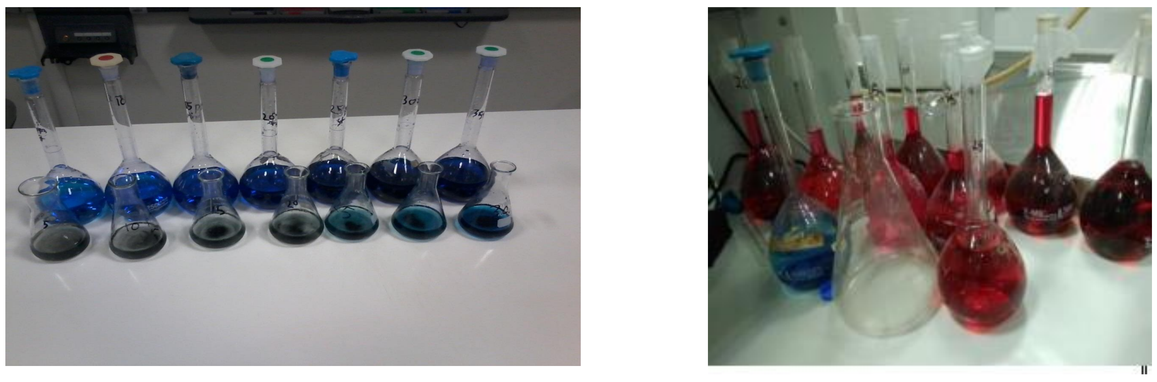


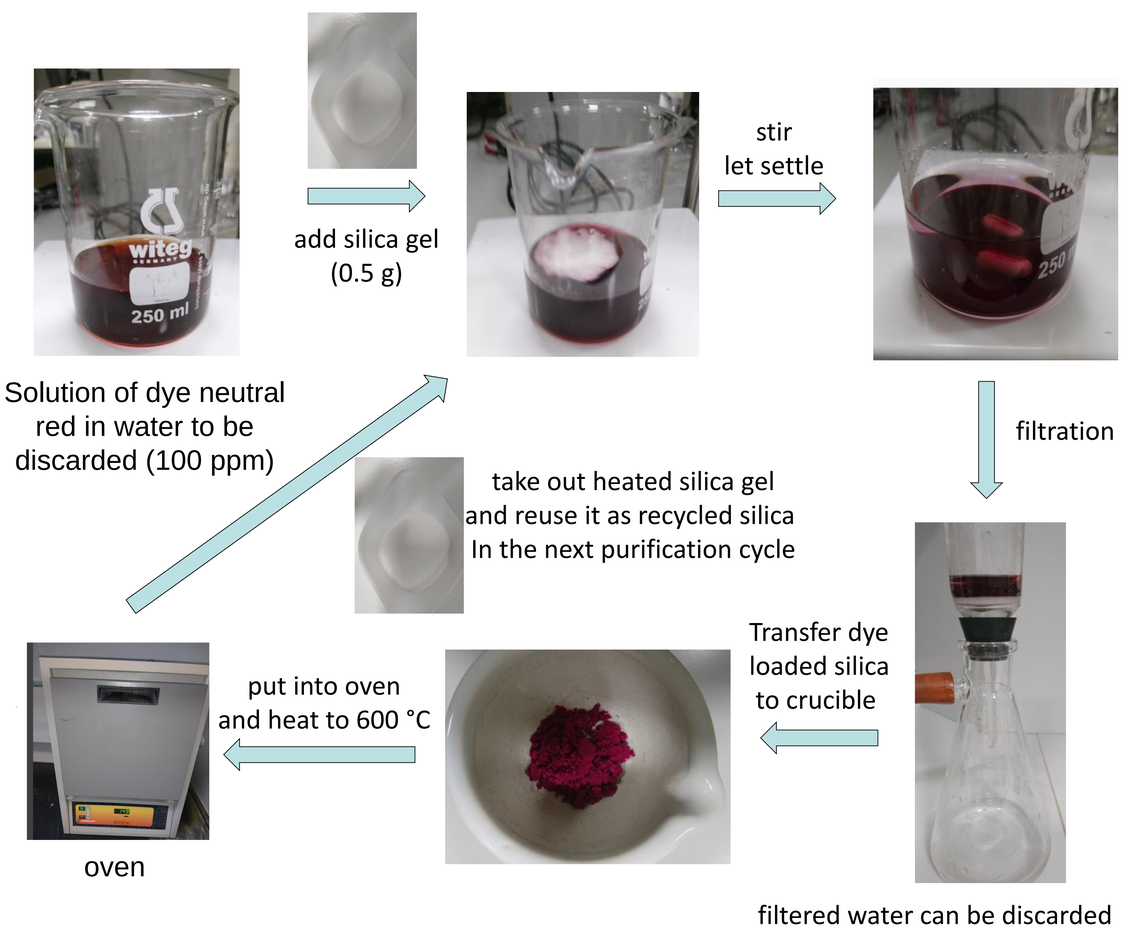
Figure 1. Typical examples of dye solutions waiting to be discarded in an educational laboratory
Left: Aqueous solutions of Nile blue; right: aqueous solutions of Deep Cherry®

Procedure: The procedure relies on the strong adsorption of many cationic dyes to silica gel. Silica gel (mainly SiO_2) is a common material that is produced industrially from sodium silicate. It is used as a moisture adsorbent, added into packaging of certain foods in satchels. It is allowed as a food additive (up to 2% content of the total in USA and up to 5% in the European Community). It is used by certain manufacturers in domestic water filters. Silica gel is available in many educational and research laboratories, where it used as the stationary phase in column chromatographic separations.

In the current study, we have looked at 12 commonly used dyes: methylene blue, malachite green oxalate, neutral red, toluidine blue O, methyl green, Bengal rose, phenol red, alizarine S, fastgreen FCF, nitrazene yellow, Nile blue, and rhodamine B.

In the procedure, add silica gel to the aqueous dye solution to be treated (ie., 0.5 g silica gel for 250 mL dye solutions loaded at 50 – 100 ppm), stir the solution for 10 min., let the silica settle, filtrate the silica (which has adsorbed the dye at this stage), discard the filtered water normally into a sink, transfer the silica gel to a porcelain crucible, put the crucible into an oven heat it to 600 °C (at this point the adsorbed dye combusts), cool down the oven, take out the crucible with the recycled silica gel, and use the recycled silica gel for the next purification cycle.

Procedure in pictures



Photos of silica gel loaded with different dyes in the process described here

Figure 3.

Conclusion: Dye-loaded water (aqueous) solutions which may involve indicators after analytical titrations, biological stains to dye organisms or tissue samples, or dye-stuff used for educational purposes are environmentally hazardous and should not be discarded directly into the municipal wastewater. Here, a process was introduced which uses silica gel as adsorbent. The silica gel is filtered off after the adsorption is complete. Then, it is heated in an oven at 600 ºC, where the dye is burnt off and the silica gel recycled. The filtrated water is clean enough to be discarded into the sink. The recycled silica gel can be reused for the purification of the next batch of dye-loaded aqueous solution.