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RESEARCH ARTICLE

Removal of copper (II) ions from Acid Mine Drainage effluents using Psidium Guava leaves powder

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Abstract

Acid mine drainage (AMD) is a serious environmental problem resulting from the weathering of sulfide minerals. The generation of AMD and discharge of dissolved heavy metals is an significant concern facing the mining industry. AMD usually contains high concentration of metals such as iron, manganese, zinc, lead, copper, and nickel. The intention of this work was to assess the ability of Psidium Guava leaves powder (PGL), in a continuous flow removal of copper (II) ions from acid mine drainage effluents using column method. The experiments were performed at constant temperature and dimensions of column and fixed bed of Psidium Guava leaves powder, with variation in bed height, initial concentrations and flow rates through the bed. Breakthrough curves were obtained from column flow studies.
The experimental results confirmed that Psidium Guava leaves powder (PGL), could be used effectively for the removal of copper (II) ions from aqueous medium.

Introduction

The elimination of toxic heavy metals from aqueous wastewaters is currently one of the mainly important environmental issues being studied. Although this issue has been studied for several years, efficient treatment choice are yet limited. Chemical precipitation, ion exchange, reverse osmosis and solvent extraction are the methods most frequently used for removing heavy metals ions from dilute aqueous streams(1). Acid Mine Drainage (AMD) is a serious hazard to human health, animals and ecological systems. This is because AMD contains heavy metal contaminants, such as Cu^{2+}, Fe^{3+}, Mn^{2+}, Zn^{2+}, Cd^{2+} and Pb^{2+} which are not biodegradable and thus tend to accumulate in living organisms, causing various diseases and disorders (2,3,4).
A number of methods have been used for acid mine drainage treatment including precipitation (5,6), electrochemical remediation (7), oxidation and hydrolysis (8), neutralization (9), ion exchange and solvent extraction (10), ion exchange and precipitation (11), titration (12) , biosorption (13), adsorption (14,15), reverse osmosis (16). Among all conventional methods for removal of heavy metal ions from acid mine drainage wastewater, the tertiary treatment using ion exchange has become a very efficient one (17,18). Studies carried out to look for new and innovative treatment technologies have focused attention on the metal binding qualities of various types of biomass (19). Biosorptive processes are generally rapid and theoretically suitable for extracting metal ions from large volumes of water
(20). Even if various types of reactors, e.g. batch, continuously stirred tank reactors and fluidized-bed columns can be used, adsorption on packed bed columns presents several advantages. It is simple to operate, gives high removal of metals and can be simply scaled up from a laboratory process. The intention of this study was to explore the effect of bed depth, flow rate and concentrations of feed metal ions on the functioning of copper (II) adsorption onto Psidium Guava leaves (PGL) in a packed-bed column.

2. Experimental

2.1. Adsorbate

All the compounds used to prepare reagent solutions were of analytic reagent grade. A stock solution of copper II (1000 mg l^{-1}) was prepared by dissolving a weighed quantity of $CuSO_4{\cdot}5H_2O$ salt in twice distilled water. The concentration ranges varied between 50 to 250 mg l^{-1} for single metal aqueous solution. Solution pH was adjusted with dilute 0.1 N H_2SO_4 or 0.1 N NaOH before column was filled with Psidium Guava leaves (PGL) powder.

2.2. Adsorbent

The Psidium Guava leaves (PGL) powder used as an adsorbent. The naturally withered guava leaves were procured locally from the Maharashtra state (India). These were first washed to remove dirt and then dried, powdered and sieved through a 200-250 mesh. The powdered tree leaves were again heated on a hot plate for about 15 minutes at 60-70^{0}C for thorough drying. And store in tightly packed glass bottle. The characteristics of Psidium Guava leaves powder are given in Table 1.

Table 1: Physical characteristics of Psidium Guava leaves powder.

Sr. No.	**Characteristics**	**Value**
1	Bulk density , gm•ML^{-1}	0.333
2	Surface area, , m^2•GM^{-1}	1.70
3	Average particle size, microns	200
4	Matter soluble in water, %	Nil
5	Matter soluble in 1M HCL, %	Nil
6	Matter soluble in 0.001M NaoH, %	Nil
7	pH	6.2

2.3. Analysis of lead (II) ions

A Chemito-201 Atomic Absorption Spectrophotometer (AAS) equipped was used to determine the concentration of unadsorbed copper (II) ions in the effluent.

2.4. Column study

In order to test the feasibility of guava leaves as an adsorbent for the removal of copper (II) ions for an industrial application, a continuous mode of adsorption was studied in a glass column (60 cm x 0.8 cm) set up. The design of the process is shown in Fig. 1.

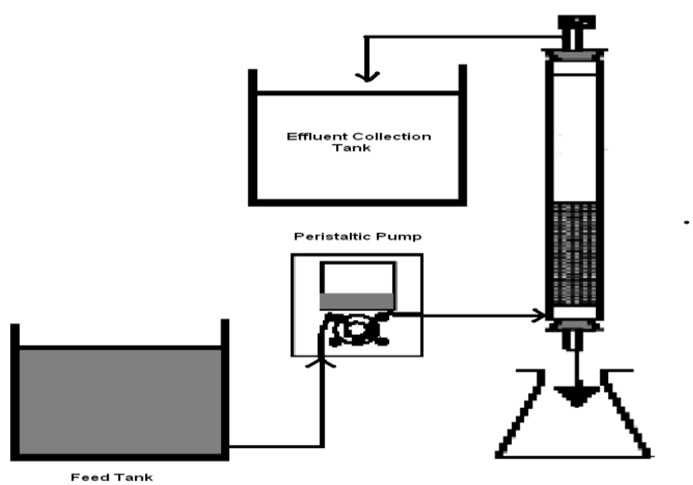

Fig. 1: Experimental set up

The intention of this step was to get better process conditions, to minimize the outlet metal ions concentration of the treated effluent, and thus to obtain lower metal ions concentrations than those set by law before dumping. Hence, the effects of several parameters influencing the adsorption process were studied separately.

Three different bed heights were used in this experimentation, respectively 20, 40, 60 cm in depth. At the bottom of the column, 3cm thick layer of glass cotton was placed to prevent any loss of adsorbent.

The pH of the feed tank solution was adjusted to 3–6 value before feeding the column. The experiments were carried out at constant room temperature (about 30^0C). The column was packed vertically while being subjected to vertically directed vibrations to facilitate particle settling and prevent size segregation near the tube walls.

The column experiments were carried out by feeding a solute solution in upward flow mode through the fixed-bed with a peristaltic pump. Samples collected periodically and the effluentwere analyzed by AAS to obtain concentration.

3. Results and discussion

3.1. Effect of bed height

The breakthrough curves obtained for copper (II) ions adsorption are illustrated in Fig. 2 for different bed height of Psidium Guava leaves powder (20,40, and 60 cm), at a constant linear flow rate of 5 lhr^{-1}.They follow the characteristic "S" shape profile produced in ideal adsorption systems. Results show that the breakthrough volume varies with bed height. This displacement of the front of adsorption with the increase in depth can be explained by mass transfer phenomena that take place in this process. When the bed depth is reduced, axial dispersion phenomena predominate in the mass transfer and reduce the diffusion of metallic ions. The solute (metallic ions) has not sufficient time to distribute into the total adsorbent mass. Moreover, an increase in the bed adsorption capacity is observed at the breakthrough point with the increase in bed height. This increase in the adsorption capacity with that in the bed height can be due to the increase in the specific surface of the adsorbent which provide more binding sites. Then it follows that a delayed breakthrough of the pollutant leads to an increase in the volume of solution treated. The increase in adsorption with that in bed height was due to the increase in adsorbent doses in larger beds which provide greater adsorption area. The breakthrough time also increased with the height of the bed. Breakthrough time is therefore the influential parameter of the process. The larger it is, the better the intra-particulate phenomena.

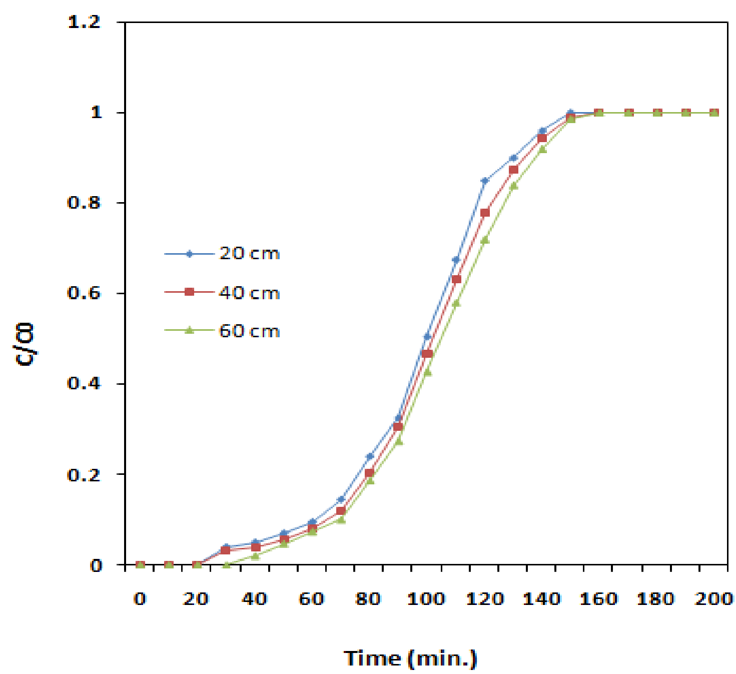

Fig. 2: Breakthrough curves of Cu(II) removal for various bed heights under conditions, flow rate: 5 lph, initial concentration 200 mg l^{-1}

3.2. Effect of inlet concentration

The effect of a variation from 100 to 200mg l^{-1} of the inlet concentration of the solution used with a linear flow rate of 5 l hr^{-1} is shown in Fig. 3. The effect of the initial concentration onto the breakthrough curves with column height set at 60 cm is shown in Fig. 3. It can be seen that a rise in the inlet metal concentration reduces the volume treated before the packed bed gets saturated.A high metal concentration may saturate the Psidium Guava leaves powder more quickly, thereby decreasing the breakthrough time. Similar results were also obtained for the sorption of copper and cadmium ions onto bone char (21) and sorption of copper and zinc by the residual biomass of the alga *Sargassum* sp. (22). These results demonstrate that an increase in the concentration modifies the adsorption rate through the bed and increases the bed adsorption capacity. However the breakthrough is reached before all the active sites of the Psidium Guava leaves powder are occupied by the metallic ions.

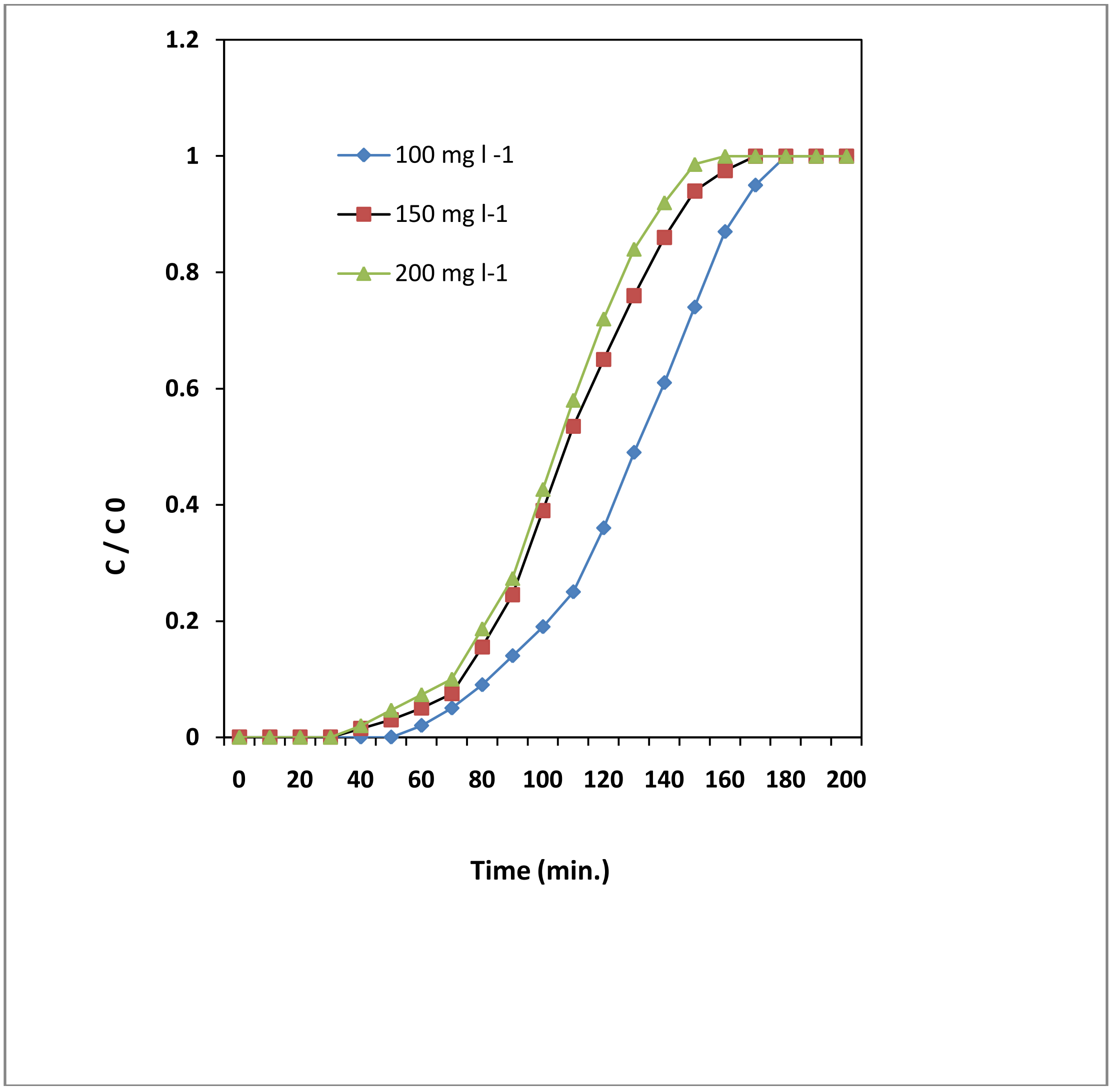

Fig. 3: Breakthrough curves of Cu(II) removal for various initial concentrations of Cu(II) solution. under conditions, flow rate: 5 lph , bed height: 60 cm.

3.3. Effect of the flow rate

To examine the effect of the flow rate through the bed height, the initial solute concentration and bed height were kept constant ($C0$ =200mg l^{-1}, bed height = 60 cm) while the linear flow rate varied from 5 to 15 lh^{-1}. Results are given in Fig. 4 show that the uptake of metal ions onto the Psidium Guava leaves powder decreases when the linear flow rate through the bed increases. An increase in the linear flow rate reduces the volume treated efficiently until breakthrough point and therefore decreases the service time of the bed. This is due to the decrease in contact time between the metal ions and the Psidium Guava leaves powder at higher linear flow rates. As the adsorption rate is controlled by intra-particulate diffusion, an early breakthrough occurs leading to a low bed adsorption capacity. These results are also in agreement with the referred literatures (22). When the linear flow rate decreases the contact time in the column is longer, intra-particulate diffusion then becomes effective. At a higher flow rate, the Psidium Guava leaves powder gets saturated near the beginning, certainly because of a reduced contact time, a larger amount of ions adsorbed on the Psidium Guava leaves powder and a weak distribution of the liquid into the column, which leads to a lower diffusivity of the solute among the particles of the Psidium Guava leaves powder.

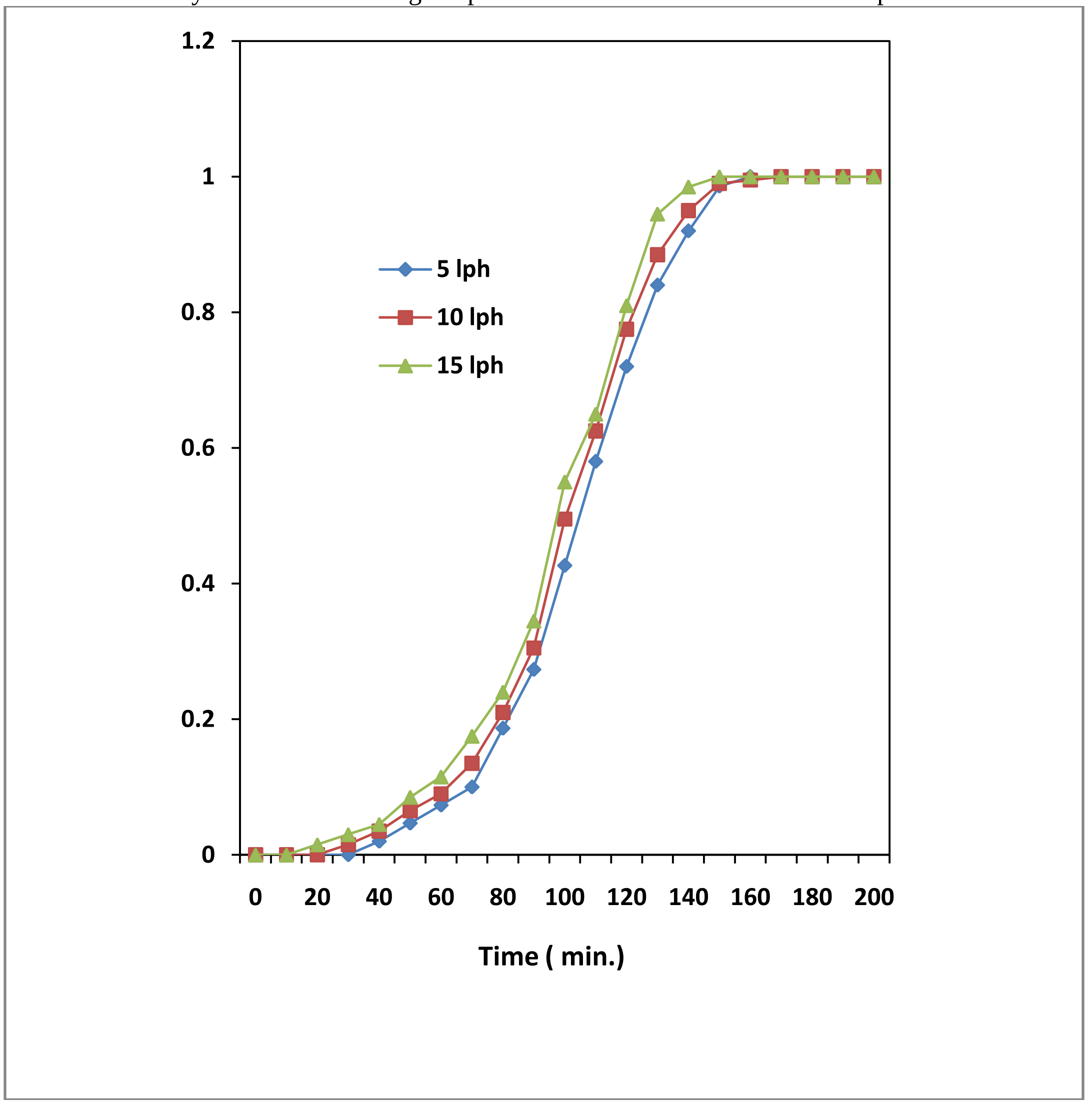

Fig. 4: Breakthrough curves of Cu(II) removal for various flow rates , under conditions, bed height: 60 cm, initial concentration:200 mg l^{-1}

4. Conclusion

Copper can be removed from aqueous solutions very effectively by means of the column exchange process on natural Psidium Guava leaves powder. Adsorption of copper (II) ions through Psidium Guava leaves powder in a packed bed column is an economically feasible technique for removing metal ions from a solution. The process allows treatment of a given volume of effluent by using a minimal mass of adsorbent which concentrates maximal content of metal. The adsorption breakthrough curves obtained at different flow rates indicate that an increase in flow rate decreases the volume treated until the breakthrough point and therefore decreases the service time of the bed. Low-cost, efficient, readily accessible materials can be used in place of activated carbon or ion-exchange resins for the removal of heavy metals from solution. Therefore, comparisons of the adsorbents are difficult because of inconsistencies in data presentation.

References

1. G. Rich, K. Cherry, Hazardous Waste Treatment Technology, Pudvan Publishing Co., New York, 1987.

2. Moreno, Natalia, Querol, Xavier, Ayora, Carles, Utilization of zeolites synthesized from coal fly ash for the purification of Acid MineWaters. Environ. Sci. Technol. 35, (2001),3526–3534.

3. Myroslav, Sprynskyy, Boguslaw, Buszewski, Artur, Terzyk P., Jacek, Namiesnik, Study of the selection mechanism of heavy metal (Pb2+, Cu2+, Ni2+ and Cd2+) adsorption on clinoptilolite. J. Colloid Interface Sci. 304, (2006),21–28.

4. Bailey, S.E., Trudy, J., Olin, T.J., Bricka, M.R., Adrian, D.D., A review of potentially low-cost sorbents for heavy metals. Water Res. 33 (11), (1999),2469–2479.

5. M.M. Matlock, B.S. Howerton, D.A. Atwood, Chemical precipitation of heavy metals from acid mine drainage, Water Res. 36, (2002), 4757– 4764.

6. J.M. Hammarstrom, P.L. Sibrell, H.E. Belkin, Characterization of limestone reacted with acid mine drainage in a pulsed limestone bed treatment system at the Friendship Hill National Historical Site, Pennsylvania, USA, Appl. Geochem. 18, (2003) ,1705–1721.

7. M.M.G. Chartrand, N.J. Bunce, Electrochemical remediation of acid mine drainage, J. Appl. Electrochem. 33, (2003), 259–264.

8. H.R. Diz, J.T. Novak, Fluidized bed for the removing iron and acidity from acid mine drainage, J. Environ. Eng. 124, (1998) ,701–708.

9. I. Doya, J. Duchesne, Neutralisation of acid mine drainage with alkaline industrial residues: laboratory investigation using batch-leaching tests, Appl. Geochem. 18, (2003), 1197–1213.

10. B.A. Bolto, L. Pawlowski, Wastewater Treatment by Ion Exchange, E. & F.N. Spon Ltd., New York, 1987.

11. J.W. Wang, D. Bejan, N. Bunce, Removal of arsenic from synthetic acid mine drainage by electrochemical pH adjustment and co-precipitation with iron hydroxide, Environ. Sci. Technol. 37, (2003), 4500–4506.

12. D.R. Jenke, F.E. Diebold, Recovery of valuable metals from acid mine drainage by selective titration, Water Res. 17 (1983), 1585–1590.

13. S. Santos, R. Machado, M.J.N. Correia, Treatment of acid mining waters, Miner. Eng. 17 (2004), 225–232.

14. M.M. Nassar, K.T. Ewida, E.E. Ebrahiem, Y.H. Magdy, Adsorption of iron and manganese ion using low cost materials as adsorbents, Adsorpt. Sci. Technol. 22, (2004), 25–37.

15. A.B. Jusoh, W.H. Cheng, W.M. Low, A. Noraaini, M.J.M.M. Noor, Study on the removal of iron and manganese in groundwater by granular activated carbon, Desalination 182 (2005) 347–353.

16. US EPA report, 14010 DYG8/71 Acid Mine waste treatment using reverse osmosis, Washington, DC, 1971.

17. R. W. Gaikwad, V. S. Sapkal and R. S. Sapkal, Ion exchange system design for removal of heavy metals from acid mine drainage wastewater Acta Montanistica Slovaca Ročník 15, 4, (2010),298-304

18. R.W. Gaikwad , R.S. Sapkal , and V.S. Sapkal Removal of Nickel Ions from Acid Mine Drainage by Ion Exchange, J. Int. Environmental Application & Science, Vol. 7 (1): (2012),37-43.

19. A.K. Bhattacharya, C. Venkobachar, Removal of Cadmium (II) by Low Cost Adsorbents, J. Environ. Eng.—ASCE 110 (1984) 110–122.

20. J.M. Brady, J.M. Tobin, J.C. Roux, Continuous fixed bed Biosorption of Cu^{2+} ions: Application of a simple parameter mathematical model, J. Chem. Technol. Biotechnol. 74, (1999) ,71–77.

21. D. C. K. Ko, J. F. Porter, and G. McKay, "Film-pore diffusion model for the fixed-bed sorption of copper and cadmium ions onto bone char," Water Research, vol. 35, no. 16, pp.(2001) , 3876–3886,

22. Valdman, E.; Erijman, L.; Pessoa, F.L.P.; Leite, S.G.F. Continuous biosorption of Cu and Zn by immobilized waste biomass *Sargassum* sp. *Process Biochemistry* vol. 36 issue 8-9 March, (2001), p. 869 – 873