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Wastewater Minimization and Reuse in Mining Industry in Illawarra Region

H. B. Dharmappa, M. Sivakumar, and R. N. Singh

Department of Civil and Mining Engineering
University of Wollongong
Northfields Avenue, Wollongong 2522, Australia

ABSTRACT

This paper forms a part of an overall research program concerning assessment of mine water quality in the Illawarra region. The project includes the determination of quality of mine water supply, influent and effluent from the mine and the processing plant and its discharge into the environmentally sensitive adjacent creeks or receiving water-courses. All mines in the Illawarra region operate and discharge its effluent under licence conditions from the NSW Environmental Protection Authority (EPA). With the introduction of stringent new water quality guidelines for receiving water, improved quality of mine water effluent is expected by the community as well as by the regulatory bodies. In order to meet more stringent water quality requirements and due to dynamic nature of mining operations, it is necessary to regularly monitor the water quality and periodically review the existing treatment methods. In this direction, an overview of overall waste management in a mining industry including identification and general characteristics of various wastewater sources, application of waste minimisation methods, segregation of waste, reuse of effluent and options for final disposal is undertaken. Various alternative wastewater treatment systems are presented for treating the effluent for ~~*reuse or final disposal.*~~ The treatment methods range from traditional treatment using chemical dosing in detention ponds to more sophisticated membrane processes, eg., microfiltration and reverse osmosis with the goal of recycling mine effluents for industrial or potable uses.

INTRODUCTION

Recently, environmental considerations have achieved more importance in the mining industry. One of the major environmental impact due to the mining industry is its wastewater disposal into the natural water body. The production of wastewater varies from mine to mine. Irrespective of the quantity of wastewater produced from these industries, the approach for the overall waste management should be fairly uniform with an emphasis on the wastewater minimisation and reuse.

WASTEWATER MANAGEMENT STRATEGY

Typical steps involved in any industry related waste management strategy includes:

1. Identification of sources and characteristics of wastewater
2. Volume and strength reduction of wastewater
3. Segregation of wastewater
4. Reuse of wastewater
5. Final disposal

In any wastewater management application, the first step is the identification of sources of wastewater and characterisation of the same. This is closely followed by the wastewater minimisation step, which includes volume and strength reduction and segregation of waste streams. The goal of volume and strength reduction is to minimise or eliminate the wastewater being generated from the industry. The steps involved in the volume and strength reduction are: (1) Conserving water use; (2) Changing industrial production to decrease wastes; (3) Recycle of wastewater within the industry (eg., use of mine water for dust suppression); and (4) Elimination of batch or slug discharges of process wastes. In most cases there will be some effluent generated even after applying volume and strength reduction. This wastewater has to be segregated depending on the characteristics of the individual waste streams. The next step is to investigate the reuse options for each of the individual waste streams after certain level of treatment. Finally, if the reuse option is not feasible for any of the streams, they must be disposed of suitably after appropriate treatment. The decision process involved in the overall wastewater management is depicted in Figure 1.

SOURCES AND CHARACTERISTICS OF WASTEWATER

The main sources of wastewater from a mining operation in the Illawarra region can be broadly classified into:

1. Mine water
2. Process wastewater
3. Sewage
4. Surface runoff

Mine water

The mine water is the probable source only in the case of underground mining. The source is seepage from the excavated area of the mine. The mine water is collected in underground sumps with a nominal retention time. There is an opportunity for recycle of mine water in the areas of fire fighting and underground dust suppression within the mining complex.

The quantity of the mine water greatly depends on the level of ground water table and the type of rock mass. The quality of the mine water varies widely from mine to mine depending upon the local conditions. However, from the available data (Rozkowski & Rozkowski, 1994; Singh, 1994; Sivakumar et al., 1994b) the following general characteristics can be identified:

1. High total dissolved solids (500 - 2000 mg/L)
2. High hardness (500 - 2000 mg/L as $CaCO_3$)
3. Low suspended solids (10 - 100 mg/L)
4. Low BOD (5 mg/L)
5. Low COD (10 - 100 mg/L)
6. Near neutral pH (7-9.5)
7. High conductivity (600 - 10,000 μs /cm)
8. High apparent colour (30 - 600)
9. Moderate concentrations of other minerals (K, Ca, Al, etc.)

As seen above, the mine water consists of a considerable amount of dissolved minerals which give rise to increase in water hardness. The pH indicated here is particularly for Illawarra region. In most of the other regions the pH can be as low as 2 - 3 resulting in acid mine drainage. This low pH is mainly due to oxidation of sulphides in coal.

Process Wastewater

The process wastewater is generated by the wash down facilities in the workshop, wash down bay, coal conveyor cleaning, the dust suppression facility, oil storage and diesel filling area, and on-site mineral processing facility. The likely contaminants are oil, coal, and other solid materials. Here again, the quantity and the characteristics of the wastewater are widely variable. However, considering the nature of the wastewater sources and the data given by Sivakumar et al. (1994b), the following general characteristics of the process wastewater can be derived:

1. High suspended solids (100 - 2,000 mg/L)
2. Near neutral pH (7 - 9)
3. Moderate dissolved solids (100 - 500 mg/L as $CaCO_3$)

Sewage

Domestic facilities like bath house, toilets, office kitchen, canteen, etc. produce sewage which is similar to the characteristics of a typical domestic wastewater. The wastewater production can be taken as 50 L per capita per day.

The wastewater characteristics of the sewage would be similar to the weak sewage expected from a commercial or institutional establishment. Typical characteristics for the sewage can be

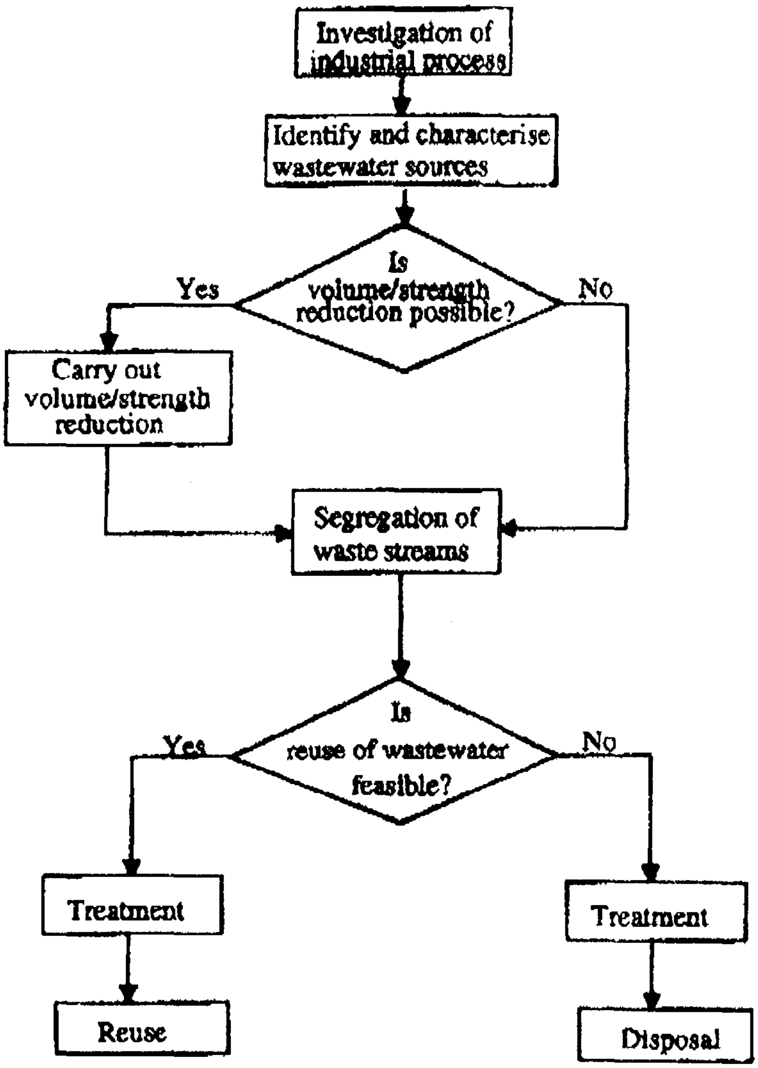

Figure 1 Waste management strategy in an industry

taken as given in Table 1 (Metcalf & Eddy Inc., 1991). Evidently, unlike other mine waters, the sewage consists of significant amount of organic contaminants.

Parameter	Concentration
Total dissolved solids, mg/L	250
Total suspended solids, mg/L	100
BOD, 5 day, mg/L	110
Chemical oxygen demand, mg/L	250
Total nitrogen, mg/L	20
Total phosphorus, mg/L	4
Chlorides, mg/L	30
Sulfates, mg/L	20
Alkalinity, mg/L as $CaCO_3$	50
Grease, mg/L250	50

Table 1 Typical characteristics of sewage (Metcalf & Eddy Inc., 1991)

Surface Run-off

During moderate to heavy storms, the mining operations at the site produce a large volume of surface run-off which must be controlled and treated. Surface run-off can be computed by knowing the land area exposed to direct rain, type of land use, and the rainfall rate.

The waste characteristics of the surface run-off depends largely on the type of the mining operation as well as on the land use of the exposed area and the amount of rainfall. Table 2 presents the characteristics of surface run-off from one of the colliery in New South Wales, Australia (Sivakumar et al., 1994a). As seen in Table 2, the suspended solids and total iron content in the effluent is considerably high, where as the dissolved solids are moderate.

Parameter	Concentration
Total suspended solids, mg/L	400 - 600
Total dissolved solids, mg/L	200 - 300
Conductivity, µs/cm	300 - 700
Total iron, mg/L	8 - 11
Colour	Black

Table 2 Typical surface run-off characteristics after storm events (Sivakumar et al., 1994)

VOLUME AND STRENGTH REDUCTION

After the identification and quantification of various sources of wastewater, the immediate task is to identify ways by which the volume and strength of the wastewater can be reduced. There may be a scope for the volume/strength reduction in the case of mine water through in-mine sealing of water inrushes such as grouting (Kesseru, 1994). Also, there is ample scope for volume/strength reduction in the cases of process wastewater, surface run-off and sewage. In the case of process wastewater, it is possible to minimise the use of water for washing purposes. This can be achieved by several means, viz., eliminating hosing down of dirt, reducing the number of taps in the mine area and controlling the pressure at the tap. Cleaning of floor and equipment can be done with a vacuum cleaner. Also, appropriate house keeping within the mining area, would help greatly in reducing the strength of the wastewater.

In the case of surface run-off, the waste production can be reduced by increasing the vegetation cover in the area, as well as by reducing the spillage of the mined material on the land area.

Finally, as far as sewage is concerned, by installing toilet systems with dual flushing and appropriate training for the employees for water conservation would greatly help in volume reduction.

SEGREGATION OF WASTEWATER

As listed earlier, there are basically four streams of wastewater being generated by a typical mining activity in the region, viz., mine water, process wastewater, sewage and surface run-off. Out of these four sources, sewage is the organic waste and the rest are essentially inorganic wastes. Further, the mine water consists of more dissolved solids and less suspended solids compared to process wastewater and surface run-off. The latter two mainly contains suspended solids with relatively low to moderate dissolved solids. As the characteristics of each of the wastewater stream significantly differs from each other, it is better to treat each one of the streams separately in order to reuse or dispose of the wastewater.

REUSE OF WASTEWATER

The most important parameters, which influence the reuse potential of wastewater are:

1. Quantity of wastewater;
2. Characteristics of wastewater;
3. Quality requirement of the reuse application;
4. Availability of treatment technologies; and
5. Availability of fresh water.

The quality requirement solely depends on the kind of reuse. If the treated water is to be used for potable purposes, the final effluent should meet the set drinking water quality standards set by NHMRC (1994) or by World Health Organisation (1984). Apart from the potable water reuse, the effluent from the mining facility could be used as process water, and for gardening, agriculture and forestry applications. Depending upon the nature of reuse, the effluent has to be treated appropriately. Some of the typical flow sheets for wastewater treatment are given in Figures 2 and 3.

One of the most conventional treatment systems is a combination of coagulation, flocculation and granular filtration for solid liquid separation, and softening process for the removal of hardness causing material as shown in Figure 2(a). This could be an appropriate system for the recycling of mine water as suggested by Singh (1994). The author reported a case of mine water reuse for potable purposes in an arid area, where in severe shortage of water supply is experienced. In this case the mine water is of substantial quantity and only the contaminant which is found to be objectionable, as far as drinking water quality requirement is concerned, is hardness. This can be efficiently removed by a softening process.

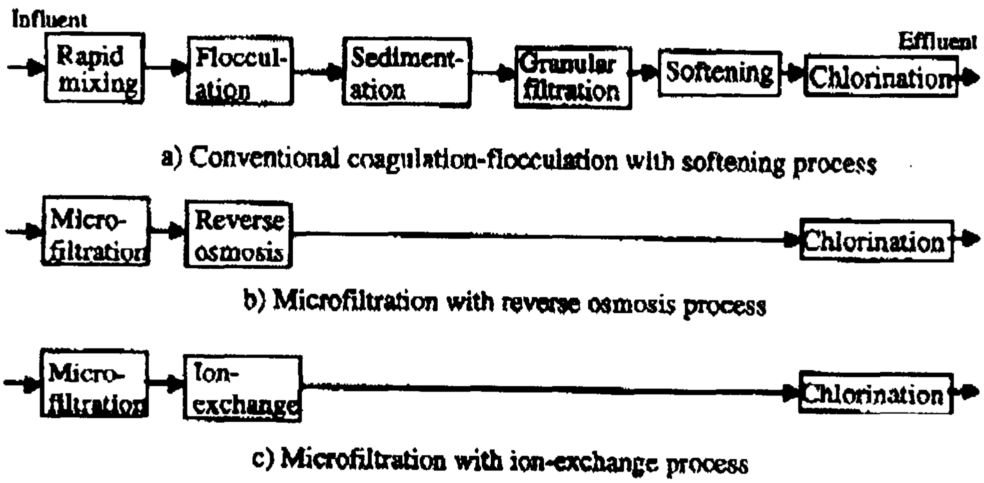

Figure 2: Typical flow sheets for effluent treatment for reuse purposes

Besides several conventional treatment processes like, coagulation, flocculation, filtration, sedimentation, ion-exchange, etc., recently membrane processes (such as microfiltration, ultrafiltration and reverse osmosis) are finding increasing acceptance in the water and wastewater industries as alternative solid-liquid separation processes. Mainly because of their ability to produce high quality water with better reliability. These systems have so far proved, their technical superiority over the conventional systems. However, their economical viability has to be worked out on the case by case basis. As shown in Figures 2(b) and 2(c), the microfiltration process is used to remove suspended contaminants, while reverse osmosis and ion exchange processes are used to remove dissolved contaminants. These system configurations can be used particularly for treating mine water. However, process wastewater and surface run-off can also be treated.

If the waste water consists of more of solid particles without much dissolved impurities, as in the case of process wastewater and surface run-off, it is possible to treat using solid liquid separation processes as shown in Figure 3(a). Figure 3(b), presents an alternative treatment flow sheet incorporating microfiltration process in the place of granular filtration. This could be further modified to replace both sedimentation and granular filtration by microfiltration as shown in Figure 3(c).

Finally, for treating sewage which essentially includes organic contaminants, it is appropriate to include biological treatment process in the flow sheet as shown in Figure 3(d). Here, activated sludge process is used to remove the organic contaminant and the residual suspended solids are removed using a granular filtration process.

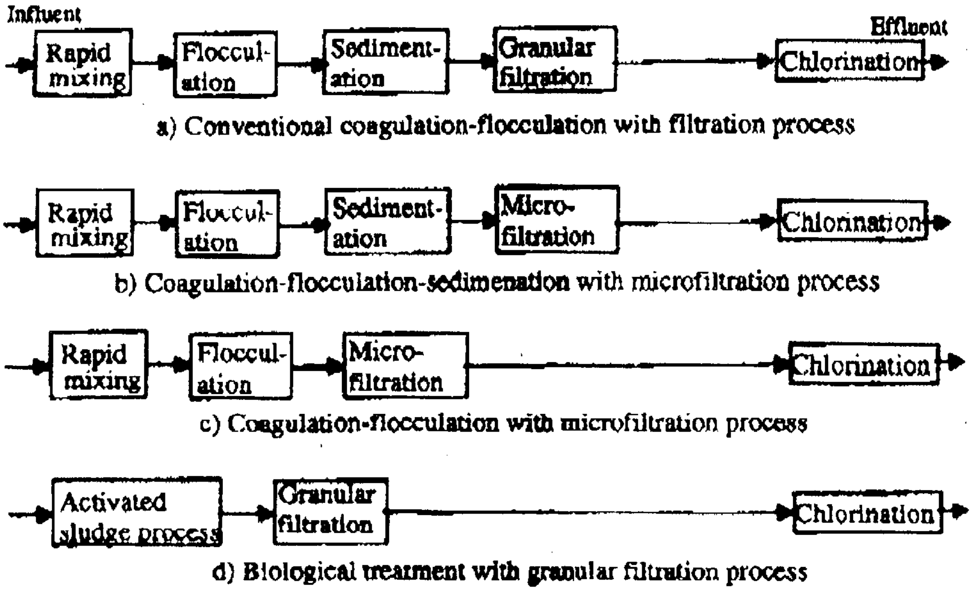

Figure 3: Additional flow sheets for effluent treatment for reuse purposes

FINAL DISPOSAL

For the final disposal of the effluent it is necessary that the wastewater meets the local effluent guidelines. In New South Wales, Australia, under current legislation mine effluent is grouped as being either site releases or discharges (McCotter, 1984). The latter are defined as the loss of water from a site by deliberate human or mechanical intervention such as pumping or the opening of valves. Licences for discharges vary from colliery to colliery depending on the classification of their local waters, but the general discharge limits can be summarised as in Table 3. However, there are more stringent guidelines set by ANZECC (1992) and in the near future the mining industry has to satisfy these standards.

Parameter	Values
Chemical oxygen demand (COD)	
Non-sensitive area	50 mg/L
Sensitive area	30 mg/L
Suspended solids (SS)	
Non-sensitive area	50 mg/L
Sensitive area	30 mg/L
pH	6.5 - 8.5

Table 3: Disposal standards in New South Wales, Australia
(Adopted from Sivakumar et al., 1992 & 1994)

Comparing the effluent characteristics outlined earlier with the disposal standards given in Table 3, it is apparent that in most cases, the effluent streams would need treatment before disposal. Some of the common wastewater treatment systems are given in Figures 4 and 5.

In most cases, the mine water just needs pH correction before disposal, which can be done through a vary simple treatment system as shown in Figure 4(a). Here, the holding pond will have a very nominal detention time (1 hr). If the mine water consists of some colour and high dissolved solids, a coagulation-flocculation with a settling pond can be used (Figure 4(c)). In this case some of the dissolved solids are removed by precipitation.

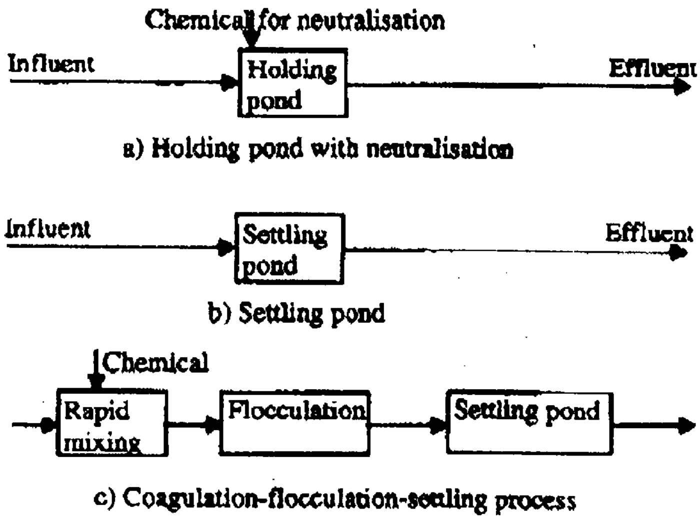

Figure 4 Typical wastewater treatment flow sheets for the final disposal

The storm water run-off also needs appropriate treatment before final disposal. In most cases, a settling pond with appropriate detention time as shown in Figure 4(b) would be sufficient to treat this wastewater. In some cases, a coagulant dosing may be required.

The mining processes such as washeries, dust suppression etc. produce effluent with high suspended solids, significant amounts of oil and some dissolved contaminants. In order to remove these contaminants a coarse solids separator, oil separator and a sorption process are required as shown in Figure 5(a). Under each of these stages there are several options available (Rubinstein et al., 1994). One such option is indicated under each stages in the figure. Similarly, another option for treating process wastewater is given in Figure 5(b), which is adopted at Cordeaux Colliery (Australia), oil is initially removed by a corrugated plate interceptor. Then the effluent flows into the primary settling pond where further oil is separated by a skimmer. The oils are collected in a central sump for subsequent removal. The settling pond's, other function is that of settling basin which allows partly clarified water to be drawn off to a filter lagoon, where the effluent is polished to meet the desired effluent standards (Sivakumar et al., 1994b).

The domestic sewage from the mining industries can be treated with biological treatment systems such as activated sludge process (Figure 5(c)) or trickling filter system (Figure 5(d)).

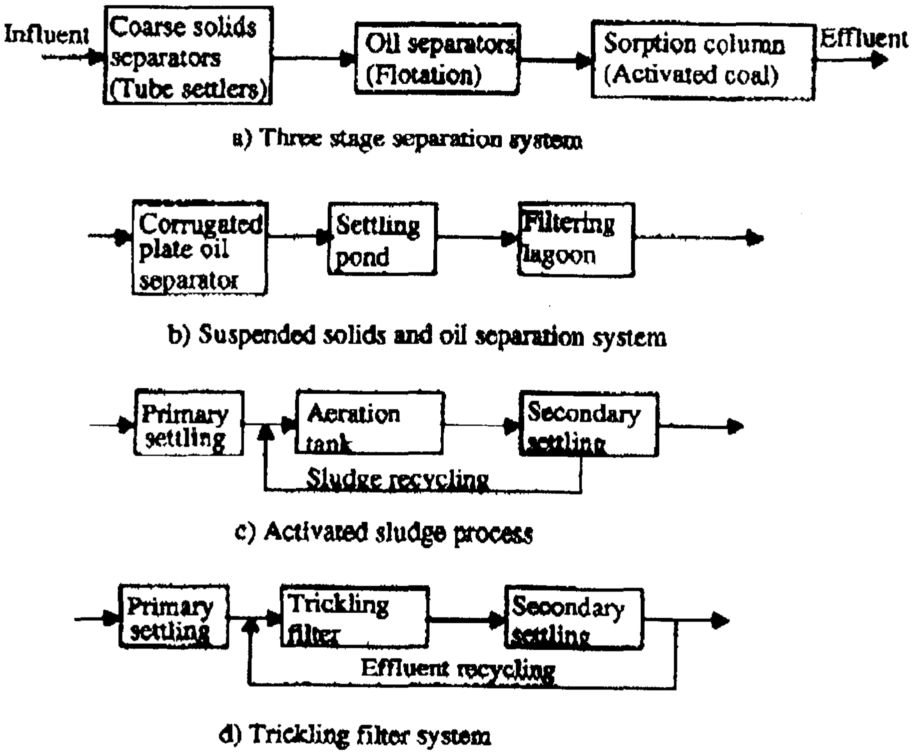

Figure 5 Additional wastewater treatment flow sheets for the final disposal

CONCLUSIONS

The above discussions indicate that there is an ample scope for the application of waste minimisation and reuse concepts for the wastewater management in mining industry. The concept of waste minimisation in industries is fairly a recent concept. It emphasis on the minimisation or elimination (zero discharge) of waste being generated, at the source itself. The waste which can not be eliminated is segregated into various streams depending on its characteristics and then treated appropriately . The treatment is carried out either individually or by combining more than one streams. This paper suggests different ways of minimising wastewater at source and segregates the remaining effluents into four categories. Further it identifies several treatment options which could be used for treating the wastewater for reuse or final disposal. Also, several membrane processes are proposed instead of conventional treatment unit operations. Although, the membrane processes are technically superior, their economic viability has to be investigated. This paper is the product of an ongoing investigation on the application of membrane processes for mine effluent reuse. So far, only preliminary investigations have been carried out, more details would be available in a future publication.

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