Chapter 9

PREVENTION, PREDICTION, MANAGEMENT & TREATMENT

9.1 Prevention mechanisms

The impacts of Acid Mine Drainage can be minimised by:

- Preventing water from getting to the pyrite by diverting rainwater away from workings or dumps.
- Preventing air from getting to the pyrite by compacting coal discard in thin layers.
- Removing water entering pyritic mines as soon as possible to minimise residence time.
- If acid mine drainage cannot be prevented, treating it by neutralisation with lime; in extreme cases a biocide such as bromine can be added to kill the acidifying bacteria. However, large quantities of bromine can become an additional source of pollution.
- Using passive water treatment technology where small seepage flows from abandoned workings, back-filled areas and dumps are acid and mineralised.

The potentially acid generating material should be prevented from mixing with air and water. Once the reactions begin, it is virtually impossible to completely stop AMD. The challenge is thus to isolate and contain the potentially toxic parts of the waste. The most reliable method for preventing AMD is to submerge the waste rock or tailings under water. This will prevent exposure to oxygen. The success of this method depends on keeping the water cover and dam structures intact forever.

A mitigation strategy proposed by a number of mines (including coal mines) in British Columbia is the use of blended dumps. The theory is that the combination of potentially acid and potentially neutral waste products will result in non-toxic drainage. In the case of coal mining, under certain blending criteria, projects have been successful (Kleinmann, 1990).

9.2 Prediction techniques

The science of predicting AMD is still far from conclusive. When attempting to predict AMD, the questions that need to be answered include:

- What is the acid-generating potential and neutralisation potential of the different rock types that will be exposed during the mining process?
- What potential contaminants/metals occur in the rocks that will be exposed?
- Under what conditions will exposure and transport of the contaminants take place at the mine site?

(Coastech Research Inc., 1989).

9.2.1 Statistic testing

This level of test involves the description of different characteristics of rock types at the mine site, with an eye to finding those components that are likely to generate acid and those that may buffer or neutralise the acidic potential of the mine waste. Acid Base Accounting (ABA) is one of the main preliminary tests run in assessing acid potential. A measure is made of the bulk amounts of acid-generating and acid-neutralising materials drawn from key areas in the mine site. Minerals containing sulphur, particularly sulphides such as pyrite, have the potential to generate acid when exposed to air and water. Other groups of minerals, such as carbonates e.g. calcium carbonate, can buffer or neutralise acidity. In ABA the acid-generating and –neutralising potential of multiple samples are compared, to see whether they may be expected to balance each other out. However, this is only a laboratory test and cannot account for many environmental and geochemical factors that may alter the chemical interaction between the acidic and basic components of the rock.

9.2.2 *Kinetic testing*

This is usually the nest step after ABA and is a more sophisticated stage of testing. Typical tests include "humidity cells" that can combine larger samples of mine waste with air, water and bacteria. This enables analysts to observe the rate at which acidification occurs over longer periods of time i.e. months. However, if kinetic testing is rushed or carried out improperly it is subject to failure and the distortion of results.

Generation of Acid Mine Drainage is more of a problem where coals have a high pyritic sulphur content e.g. 4% or more (diPretoro and Rauch, 1988).

9.3 Management strategies

Management of acid mine drainage is required by law in South Africa. There are three distinct groups of legislation applicable to water management, and therefore the associated potential problem of acid mine drainage.

Firstly, the Department of Water Affairs and Forestry (DWAF) provides legislation in the form of the new National Water Act, Act 36 of 1998. The aim of DWAF is to phase out General Effluent Standards and employ the Receiving Water Quality Objectives. It also supports the concept of managing water in terms of catchments.

Secondly, the Department of Minerals and Energy (DME) has provided legislation to which the Minerals Act is central.

Thirdly, the Department of Environment Affairs (DEA) has provided legislation in the form of the Environment Conservation Act. This Act encourages the concept of Integrated Environmental Management (Barnard, 1999).

9.3.1 *Mineral and mining management*

In order to address the environmental impacts of mining, a system for the management of these impacts was developed. This system forms a vital component of the Minerals Act 50 of 1991, section 9. In the 1990s, power was transferred from the mining houses to the structures for environmental governance existent in South Africa. Mining regulations were already in place since the 1970s, but their enforcement had not been given much attention. There was much other legislation that either anticipated or affirmed the rise of environmental rights over the previous, unchecked, right to exploit minerals. This legislation included the following:

- Environment Conservation Act 73 of 1989
- Development Facilitation Act 67 of 1995
- Mines Health and Safety Act 29 of 1996
- Bill of Rights in the Constitution of the Republic of South Africa Act 108 of 1996
- National Environmental Management Act 107 of 1998

The first application of the holder of a mineral right is for authorisation, in principle, to use mineralised land for mining. Mining authorisation is issued only once the Director of the Department of Minerals and Energy is satisfied with the "manner in and scale on which the applicant intends to mine the mineral concerned". The applicant must also satisfy the Director "with the manner in which such applicant intends to rehabilitate disturbances of the surface" and that "such applicant has the ability and can make the necessary provision...to rehabilitate such disturbances".

The Development Facilitation Act (DFA) lays down "general principles governing land development throughout the Republic". The DFA focuses on maximising the yield of land.

The Constitution of the Republic of South Africa Act protects the rights of everyone not to "...be deprived of property except in terms of law of general application". Depending on its location and management, a mine can act adversely on these rights by for example subjecting people to noise and polluted air or water.

The Environment Conservation Act contains overarching legislation. An important source of principles is the general environmental policy determined in terms of section 2. It established the following:

- The need for sustainable development
- The need for a holistic evaluation of projects
- The need to internalise external costs
- The requirement of the judicious use of land
- The need to prevent the destruction of wetlands and other environmentally sensitive areas
- The need for the application of scientific conservation principles in all land-use planning
- The undertaking of planned analyses of large-scale or high-impact development projects before embarking on them
- The involvement of the public in development planning

It is important to note that the Environment Conservation Act should be read with the National Environmental Management Act.

The National Environmental Management Act develops the principles first set out in the general environmental policy of the Environment Conservation Act.

As yet, no checklist exists to make it easier to evaluate applications in terms of section 9 of the Minerals Act. Thus the effect of the proposed activities must be evaluated against the principles set out, and in this respect DME officials are obliged to provide assistance (Barnard, 1999).

9.3.2 Water management

The White Paper *A National Water Policy for South Africa* issued by the Department of Water Affairs and Forestry in April 1997 established the basis for future water legislation. The National Water Act 36 of 1998 is structured around the following principles:

- Water is scarce
- It is unevenly distributed
- It belongs to all people
- All aspects of water must be managed in an integrated manner
- Water management must achieve sustainable use and must protect its quality

A number of underlying principles to the National Water Act deserve special mention and a brief discussion.

The ancient Roman law that water belongs to the state, which holds this resource in trust for the nation, is an internationally accepted principle. This is the basis of the Act.

In the hierarchy of water allocation the 'reserve' is regarded as priority use. The reserve is made up of two parts i.e. the basic human needs reserve and the ecological reserve. The basic human needs reserve provides for the essential needs of individuals served by the water resource and includes water for drinking, food preparation and personal hygiene. The ecological reserve relates to the water required to protect the aquatic ecosystems of the water source. The purpose of determining such reserves is to meet the requirements of sustainable use, not only of water but also of the ecosystems where it occurs.

Once the water for the reserve has been allocated, the priorities for further water allocation will depend on every applicant's circumstances and the particular characteristics of every water management area. In section 21 of the Act, lawful water uses are defined. These uses go beyond the traditional use of water for domestic, agricultural, recreational or industrial purposes. Waste disposal in a manner that may detrimentally impact on a water resource is included in the definition of water use. The sub-categories of industrial use include the use of water for cooling, steam generation, as process water, as production water and as utility water. The fitness of the water for use is determined in terms of its corrosiveness, scaling, fouling, forming of blockages, foaming, gas production, contamination, coagulation, turbidity, waste disposal and a number of other factors. The constituents analysed include alkalinity, chemical oxygen demand, pH, chloride, iron, manganese, silica, sulphates and several others.

It is essential that the quality of water should not be degraded and that water that has been polluted is purified to acceptable levels. As issues arose over the years, the integrated water quality management system evolved. In order to implement the aims of the receiving water quality objectives, water quality guidelines were compiled, based on the requirements of recognised water users; the closely aligned water quality management objectives, which recognise the water quality requirements of the water users as well as economic, social, political, legal and technological considerations were formulated; and site-specific effluent standards or other measures were set to ensure that the water quality management objectives determined for the particular water body would be met.

These are just some of the objectives that form the legal framework within which we must consider the relationship between water resources and the activities of the coal mining industry (Barnard, 1999).

9.3.3 Waste management

The Concise Oxford Dictionary defines waste as 'unwanted or unusable remains or by-products'. In the course of coal mining activities, many products for which there is no apparent use are produced. The variety of matter constituting waste is staggering. The wide variety of adverse impacts caused by waste has resulted in the development of many waste management measures.

The threat posed to human health by badly managed waste is addressed in several acts. The Health Act 63 of 1977 regulates conditions dangerous to health, such as the disposal of sludge or other waste products at a water purification works (section 37 (f)). The Hazardous Substances Act 15 of 1973 provides for the control of hazardous substances. These substances are categorised in SABS Code 0228. The depositing of waste in (or with access to) water courses is illegal as it causes pollution of that water in terms of the National Water Act 36 of 1998. Such actions may also cause the destruction of vleis, marshes and watercourses in terms of the Conservation of Agricultural Resources Act 43 of 1983.

Waste management has attained a relatively high level of sophistication. Structures have been developed that control many forms of waste. They also deal with waste in an integrated manner. Waste is primarily managed in terms of the Environment Conservation Act 73 of 1989. Mining-related waste is managed in terms of the mining-related legislation discussed above i.e. the Minerals Act 50 of 1991. Department of Water Affairs and Forestry manages the disposal of waste and has compiled a set of guidelines in the form of The Minimum Requirements for Waste Disposal; and Department of Environment And Tourism manages all other aspects of waste in South Africa (Barnard, 1999).

9.3.4 Standards and guidelines

DWAF uses the concept of fitness-for-use when giving standards with which water qualities should comply. These standards are contained in several volumes; compiled by DWAF i.e. domestic, recreational, industrial and agricultural use guidelines, respectively (Appendix A2). Environmental standards will be included after the current revision of these documents. A major knowledge gap at present is the very slow development of fitness-for-use standards for all major water users in the mining industry (Barnard, 1999).

There are at present three generally accepted approaches to the prevention or control of acid mine drainage, as follows:

- Control of the acid generating process.
- Control of acid drainage migration.
- Collection and treatment of acid mine drainage.

The three options have been listed in order of preference. The objectives of acid mine drainage monitoring are thus to:

- Detect the onset of acid generation before acid mine drainage develops to the stage where environmental impact occurs. Abatement measures, if required, need to be implemented as soon as possible.
- Monitor the effectiveness of control measures.

9.3.5 Control of acid generation

- Sulphide removal or isolation
- Exclusion of water
- Exclusion of oxygen
- Temperature control
- pH control
- Control of bacterial action

Criteria that need to be considered in the selection of control measures include:

- The degree of acid-producing potential of the mine waste. This includes the nature, quantity and reactivity of sulphide minerals present, neutralising potential of the rock etc., and would be determined using geochemical testing.
- The type and physical characteristics of the waste.
- Site criteria, such as climate, topography, surface and groundwater hydrology.
- The time period for which the control measure is required to be effective.
- The sensitivity of the receiving environment to AMD.

(Bowell, Fuge, Connelly and Sadler, 1996).

9.3.6 Control of acid migration

Water entry may be controlled by:

- Diversion of all surface water flowing towards the acid mine drainage source
- Prevention of groundwater flow into the acid mine drainage source
- Prevention of infiltration of precipitation into the acid mine drainage source
- Controlled placement of acid-generating waste.

(Broughton and Healey, 1992)

9.3.7 Management design criteria

Criteria for the design of an AMD management strategy include a large number of items. These criteria consider both bench test results and industrial experience. They include:

- Feed rate and hydraulic loading of coal
- pH
- Residence time

- Reagent dosages
- Clarifier loading
- Aeration and agitation
- Recirculation

(Castelli *et al*, 1992).

9.3.7.1 The design process

The design process may be outlined as follows:

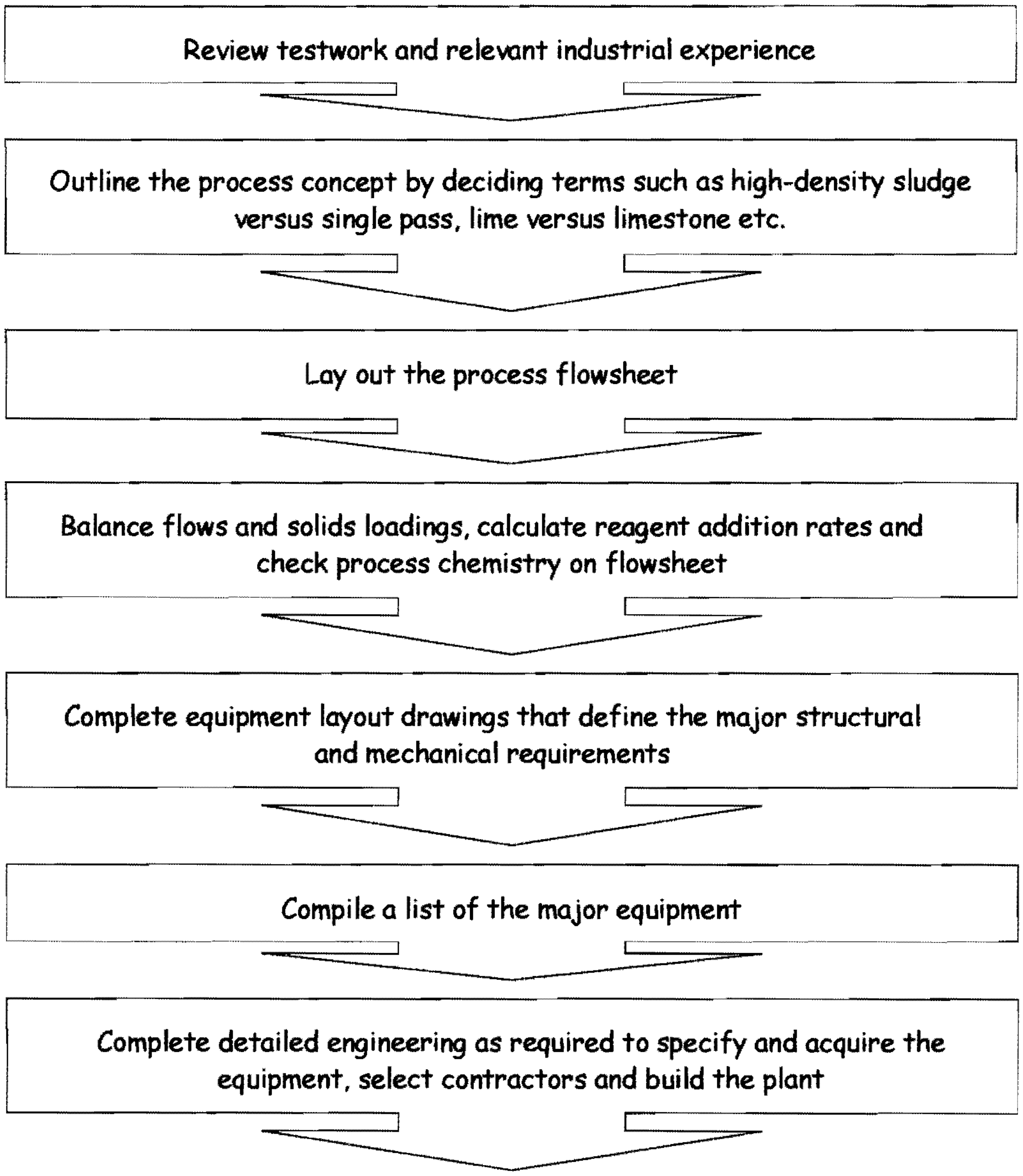

Figure 26: The design process

9.3.7.2 Modelling

The graphics oriented system uses 3D volume modelling, geostatistics and visualisation to provide integrated capabilities for precise modelling of all aspects of the geological environment. The system can also superimpose the effects of pollution. In addition, it can simulate the results of proposed reclamation and remediation measures. It can be applied in a predictive context to forecast the effects of future mining activities, and/or in a monitoring context to determine the degree and extent of acid mine drainage (AMD) related problems. The results produced support the design of economic and effective AMD prevention or containment measures. The integrated geostatistical capabilities of the system are used to determine the distribution and extent of sub-surface contamination based on isolated observations e.g. borehole sample analysis results (Costa *et al*, 1992; Houlding, 1992).

9.3.8 Water quality management objectives

In order to develop a water quality management plan for the Witbank and Middelburg Dam Catchments, or any other catchment with similar conditions, the following protocol should be followed:

- Land use practices, mining, industrial and urban developments should be quantified in terms of a specific time frame e.g. the next 20 years.
- Initial values for soil moisture, sulphate concentration in soil moisture, groundwater level, sulphate concentration in groundwater and impoundment sulphate concentrations should be carefully estimated.
- Model simulations should be conducted using all available historical meteorological and hydrological data.
- Initial estimates for the soil moisture sulphate concentrations, groundwater sulphate concentrations and impoundment sulphate concentrations should be adjusted until a steady state situation is approached.

- Parameters describing the abstraction of water, inter-basin transfer of water, point and non-point sources of sulphate pollution should be adjustable to reflect any future water quality management approach (Harpley and Geldenhuis, 1987).

It is also necessary to do the following:

- Investigate patterns of land use and their impact on surface water quality i.e. mining, industry agriculture and urban development.
- Develop insight into pollutant mobility and future catchment scenarios by modelling water quality.
- Formulate probable future land use and development scenarios for the catchment.
- Identify and formulate water quality management options.
- Develop water quality management objectives to sustain long-term acceptable water quality to all users.
- Develop a water quality information system to allow adequate feedback to catchment water resource managers.
- Establish a management structure and provide the necessary resources to implement the Water Quality Management Plan.

The water quality management structure should be of an adequate size and consist of suitably qualified manpower to answer to the needs of their management unit. It should include representatives from mining, industry, agriculture and municipalities. It must define its spectrum of recognised water users and their water quality requirements. It must also encourage representation by the most significant player in the presence and mobilisation of primary pollutants.

In order to derive a set of water quality guidelines for the water quality management strategy the following points must be adhered to:

- Recognised water users in each catchment must be identified.
- The water quality requirements for each user should be listed in terms of the variables of concern to that particular user.
- These requirements must be analysed with respect to each water quality variable and the most sensitive user must be identified.
- The requirements of the most sensitive user then determine the water quality guideline values (Pulles *et al*, 1996).

9.3.9 Future management options for the Witbank and Middelburg Dam catchments

Requirements for the future management of water quality affected by coal mining activities in the Witbank and Middelburg Dam catchments include:

- Control of mining related non-point sources of pollution.
- Control of periodic point source discharges of effluent process water from power stations.

The proposed basis for the allocation of sulphate waste load should be based on the following criteria:

- Size of the mine, expressed in terms of production in ton ROM/annum.
- Age of the mine. Expressed in terms of total historical ton ROM produced.
- Mining technology, which distinguishes between open cast mining and underground mining.
- Sulphur content of the coal itself.

9.4 Treatment technologies

Various treatment options exist for the removal of acidity or the neutralisation of pH. Chemical addition processes involve the addition of lime, soda ash or caustic soda to the water. Although lime is the cheapest and most commonly used neutralising chemical, it suffers from two drawbacks:

- It leaves no residual buffer capacity in the water
- It adds calcium to the water, thereby increasing hardness and scaling properties.

Limestone is much cheaper than other chemicals used for the purpose of neutralising acid water. However, it suffers from a number of problems:

- Slow reaction time
- Tendency to armour with iron

For these reasons, techniques have been developed to use limestone in fluidised bed reactors. The advantage of this approach is that the agitation and scouring actions compensate for the slow reaction time and the armouring effects. However, this technology is only suitable for surface applications. This is because it requires a constant input flow rate and those to underground settling tanks have been known to change by a factor of 10 or more in less than 30 minutes (Durkin, 1995).

Anoxic Limestone Drains (ALDs) are used as a passive acidity removal technique. Appropriate pre-treatment is vital to address the problems of iron and aluminium. Design guidelines are being drafted in South Africa at present (DWAF, 1998). It is understood that these systems will be best suited to post-closure applications and the treatment of isolated seeps.

AMD pollutes thousands of kilometres of streams in the Appalachian region. Abandoned coal mines produce 90% of this acidic drainage. Most of these are deep mines. This occurs largely due to the fact that no individual is responsible for treating the water with chemicals. Wetlands and anoxic limestone drains have been installed on more than 100 sites and water quality improvements have been documented through monitoring. Iron and acid reductions were consistently greater in wetlands with limestone incorporated into the substrate. In terms of anoxic limestone drains (ALDs), the following conclusions have been presented:

- Organic matter should not be placed in the drains due to micro-organism growth on the limestone.
- Larger limestone particle size (2 cm to 6 cm) helps to maintain water flow through the drain especially in those cases where some Al, Fe and grit accumulate in the drain.
- Pipes installed in the drain must be large in diameter with large perforations to reduce the potential for plugging to occur.

(Kleinmann, 1989)

AMD can be effectively treated by passing the acidic water through underground beds of limestone. The water is neutralised by picking up alkalinity from the dissolution of limestone in these drains. Metals are also precipitated from the water. Many ALDs have failed over time due to the precipitation of metals in the drain which causes clogging of the limestone pores. On the basis of laboratory experiments, it appears that increasing the ionic strength of the water entering the drain can increase the effectiveness of ALDs. For example, when sulphate is added to acid water containing ferric iron and aluminium, much greater precipitation occurs, causing the successful removal of the metal ions from the water (Logsdon and Mudder, 1995).

Abandoned coal mines cover about 200 000 acres in West Virginia. Re-mining allows an operator to remove remaining coal reserves that were left on site and rehabilitate the entire abandoned mine site to current reclamation standards, thus affording environmental enhancement of previously affected areas.

AMD from an abandoned deep mine was eliminated by re-mining the deep workings and adding alkaline overburden material during back-filling and reclamation. The quality of the receiving stream has improved due to the results of remining.

On another site, reclaiming the discard on the site with fly ash and covering it with topsoil has reduced acid discharges by 90% (Steffen, Robertson and Kirsten, 1992).

The Cheat River Basin, West Virginia, is heavily polluted by AMD. A number of watershed projects have been initiated here and limestone filling of underground mines has been effectively employed to improve water quality in the area (Steffen, Robertson and Kirsten, 1992).

Generation of electricity by coal-fired power plants produces large quantities of bottom ash and fly ash. These ashes are alkaline in nature and are thus suitable for use in surface mine reclamation to neutralise acidity and reduce the hydraulic conductivity of disturbed overburdens. A strategy for controlling AMD on surface mines is isolating and segregating acid-producing materials with a barrier to limit their exposure to air and water. Ash generated by fluidised bed combustion (FBC) boilers could be used as an alkaline barrier material, as it has high neutralisation potential. FBC ash should be mixed with a porous material e.g. conventional bottom or fly ash, to minimise hardening and encourage continual release of alkalinity (Steffen, Robertson and Kirsten, 1992).

Treatment measures can be either active systems, which require continuous operation e.g. a chemical treatment plant; or passive systems e.g. wetlands.
Collection requires collection of both surface waters and groundwater contaminated by ARD. Collection of surface flows is usually readily achieved by means of surface ditches. The collection of groundwater flows requires the installation of collection trenches, wells, or cut-off walls to force the water to flow to the surface where it may be collected (Brown, 1995).

Chemical treatment involves the elimination of acidity by neutralisation of the acid stream with an alkali reactant or combination of alkali reactants offering the best economic implications. A number of bases may be considered for neutralisation including ground limestone, slaked lime, caustic soda, soda ash, ammonia and mill tailings. After neutralisation, most metals are precipitated as their respective hydroxides or hydrated metal oxides while the associated sulphate is precipitated as gypsum (Eggert, 1994).

A common operational concern in neutralisation systems is the formation of scale on process piping, equipment and instrumentation. This is most often associated with lime processes. The composition of scale is similar to the composition of the precipitates formed in the reactions. This may be due to a number of processes, including:

- Direct precipitation on the vessel surfaces
- Entrapment of precipitate in gypsum scale owing to gypsum supersaturation
- Absorption of CO_2 from the air by calcium-saturated solutions

Such scale is generally removed by acid treatment e.g. inhibited hydrochloric acid.

Sludges resulting from neutralisation of ARD can contain gypsum, heavy metal hydroxides, heavy metal arsenates and calcium arsenate. Instability may occur when the sludge is exposed to air or solutions of differing composition, or when changes occur over a long time period due to a slow chemical reaction (Pulles *et al*, 1996).

The treatment process is straightforward. However, there are alternative methods for accomplishing essentially the same objective. Stirred tank reactors, pipeline reactors, gravity clarifiers, circular clarifiers, reactor clarifiers, hopper clarifiers and lamella clarifiers are but a few examples which will be briefly outlined.

The advantages of stirred tank reactors are:

- Improved settling properties will result when the tank contents are close to neutralisation equilibrium. This will cause any precipitates to deposit on previously precipitated material, rather than form new nuclei.
- The tank may be constructed in a wide range of sizes. This permits any reasonable residence time to be achieved.
- More than one tank may be used, in series or parallel, to permit staging of the process.
- Where physical descaling becomes necessary, the stirred tank provides better access to reactor components than a pipeline reactor.
- Batch stirred tanks can provide very good process control, because neutralisation and reagent addition can be conducted in a stepwise manner, with pH measurements or other analyses conducted between steps or prior to discharge.

The advantages of pipeline reactors are:

- Most appropriate when neutralising with a soluble reagent.
- Short reaction times facilitate more accurate reagent dosage control.
- A caustic neutralisation scheme might reduce scaling compared to a lime system.

The main advantage of gravity clarifiers is:

- The tank provides sufficient residence time and settling area to allow solids separation and sludge densification.

Advantages of reactor clarifiers include:

- Flocculation efficiency is improved by adding polyelectrolytes to high solids concentration feed in a 'flash mix' chamber, followed by a flocculation chamber.
- Flash–mixing, flocculation and sedimentation may all be achieved in one vessel.
- Clarification efficiency is improved by allowing the mixture leaving the reaction zone to pass through a bed of flocculated solids (a 'sludge blanket') in the clarification zone, which provides a filtering action.

The advantages of hopper clarifiers are:

- Developed in South Africa, this is a simple apparatus, which is easy and inexpensive to operate.
- Requires very little operator attention.
- Virtually maintenance free.

The advantages of lamella clarifiers include:

- Settling area is multiplied through the stacking of plates. In effect clarification is increased by placing a series of clarifiers one on top of the other (Wates, 1987).

9.4.1 Process development and testwork procedures

It is essential to conduct process development and treatability testwork prior to design of a treatment system for ARD. Design failures associated with new treatment systems are commonly the result of one or more of the following:

- Non-representative samples
- Insufficient bench and pilot testing

- Inaccurate estimation of hydraulic loading
- Failure to compensate for hydraulic and chemical loading variability
- Inadequate process control instrumentation (Hutchison *et al*, 1995).

9.4.1.1 Characterisation of feed

The ore and waste rock can be characterised by examining the following features:

- Physical characteristics i.e. hardness, pore water pH etc.
- Mineralogical characteristics i.e. pyrite, pyrrhotite, calcite, arsenopyrite, galena etc.
- Metal composition
- Composition of major anions

9.4.1.2 Testing

Testing for design purposes should involve analysis of the following:

- Full set of analyses on the feed sample
- Generation of a neutralisation curve
- Determination of the neutralisation reaction rate
- Small scale batch precipitation and coagulation tests
- Flocculation tests and polyelectrolyte screening
- Settling tests
- Sludge characterisation and stability tests including physical and leaching characteristics
- Batch oxidation testing (where there is a need to oxidise ferrous iron or arsenite)

9.4.1.3 Case studies

Studies that simply consider the wetland as a "black-box" and only investigate the quantity and quality of influent and effluent cannot provide information on individual processes occurring in the wetland. A better option is to use a synthetically prepared acid drainage that contains only one contaminant at a time (Kleinmann and Hedin, 1993).

Substantial improvements in water quality can be effected by maximising the residence time of the water in the wetland. Optimum treatment of acid mine drainage may be obtained by co-disposal with another effluent which has a high pH (Hedin, Narin and Kleinmann, 1994).

The U.S. Bureau of Mines has developed porous polymeric beads (i.e. resin) containing immobilised biological materials for extracting metal contaminants from wastewaters. These beads have distinct advantages over traditional methods and can be used in conventional processing equipment or low maintenance systems. The beads have removed toxic metals such as Cd, Pb and Cu from a number of different wastewaters, including acid mine drainage waters from active and abandoned mining operations. Adsorbed metals are removed from the beads using dilute mineral acids (Robinson, Carrington, Fitch, Shupe, Herrmann and Worcester, 1992).