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IMPROVING WATER MANAGEMENT BY THE INDUSTRIAL SECTOR IN SAUDI ARABIA

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ABSTRACT

Better utilization of local water resources by the industrial sector is proving to be of vital economical and environmental importance. Strategies are suggested for better management of industrial water consumption and utilization. Wastewater reuse and industrial integration are some of the strategies that can be practiced to enhance water utilization and minimize wastewater discharge to the environment. Government policies can improve water utilization by giving incentives to industries that are efficient in the utilization of water. Consumer awareness of the strategic and environmental importance of water utilization can contribute significantly towards forcing industries to follow more stringent water utilization policies.

Keywords: *water, management, industrial sector, waste, minimization*

الملخص

إيجاد طرق أمثل لاستخدام وإعادة تدوير المياه في القطاع الصناعي له أهمية قصوى وتأثير بالغ من الناحية الإقتصاديه والبيئية. في هذه الورقة يتم اقتراح استراتيجيات لتحسين إدارة المياه في القطاع الصناعي. إعادة إستخدام المياه والتكامل الصناعي هما اثنان من الحلول التي يمكن تطبيقها لتحسين استخدام المياه وتقليل النفايات في البيئة. كما أن القوانين والسياسات المتعلقة باستخدام المياه في الأغراض الصناعية يمكن أن تساهم بشكل كبير في تحسين إدارة المياه وذلك عن طريق إعطاء حوافز للصناعات التي تدير المياه بشكل أفضل.

1. INTRODUCTION

Water consumption in Saudi Arabia has witnessed a substantial increase over the last twenty years. Fast population growth, fundamental alteration in life style, and a strong government movement toward agricultural and industrial promotion caused a rapid growth in water consumption. The enormous increase in water demand has imposed two major problems: rapid depletion of national non-rechargeable water resources and a continual drop in the quality of these resources. This growth in water consumption is reflected on the growth of the demand for desalinated water. By the year 1999, the number of large scale desalination plants reached 27 Stations and the production capacity reached 775 million cubic meters, providing

more that 70 percent of the required drinking water. This data can be used as an indication for the rapid growth in water consumption, since it covers only part of the kingdom water demand and excludes many other demands such as agricultural and industrial water.

The industrial sector in Saudi Arabia has expanded rapidly over the last three decades and is expected to continue to grow with high rate. Almost all industries require the two fundamental utilities: water and electrical power to accomplish their tasks. Therefore, the industrial growth in Saudi Arabia can be measured by the increase in electrical power consumption. The annual electrical power consumption increased 16 folds since 1975 with an annual growth rate of 16%. The industrial power consumption increased on average by 11.8% annually. Industrial power consumption accounted for only 25% of the total power produced in 1996 [1]. In comparison to industrialized nations whose industrial power consumption accounts for more than 50% of the total power consumed and considering the fast movement towards industrialization, it can be forecasted, that industrial growth in Saudi Arabia will continue to rise to much higher levels.

It is anticipated that the coming decades will witness a great increase in water consumption. This rapid growth necessitates sound water planning as well as better management of existing and potential water resources. Some issues that must be considered are industrial integration, water conservation policies and consideration of wastewater reuse directly or indirectly. Rational management of water resources must be considered not only for economic reasons but also and more importantly for environmental and strategic reasons. Better utilization of water resources leads to lower wastewater release and a cleaner environment.

The lack of regulations for the water consumption by industries and the relatively low price of water, compared to the cost of wastewater treatment and reuse, have led to a great waste of water. In other words, it caused lack of optimization of water consumption. Moreover, many industries use water once through without considering the potential for reusing this water. The wasted water does not only result in economical losses, but also causes major environmental problems and national loss of water resources.

In this paper we propose different approaches for minimizing water consumption and wastewater generation by the industrial sector. We evaluate some of the local industries current practices and investigate the practices of other countries and look for ways to apply these practices to local industries.

2. TOWARDS WATER CONSERVATION

Water conservation is a strategic issue that must be addressed in Saudi Arabia because of economical, political and environmental reasons. Processes that are well designed and integrated for maximum water utilization have a strong potential to last and be profitable. For example, these processes do not have to undergo severe high cost modifications in the

instances when regulatory procedures change especially under the current trend towards globalization of environmental regulations. The environmental advantages of water conservation are numerous. Conservation in water provides better utilization of our national water resources. In addition, the release of large amounts of sanitary and industrial wastewater to the environment will eventually influence the local ecology and the land and marine biological environments.

Due to the geographical and ecological nature of Saudi Arabia, there are different water resources available for the industrial sector. These are:

1- Seawater for direct use or indirect use through heat exchangers
2- Treated wastewater
3- Desalinated water
4- Groundwater
5- Raw sanitary wastewater
6- Raw industrial wastewater

Better water management and utilization can be realized through many strategies that involve government policies and consumer awareness. In the following paragraphs, we address some of the solutions that can contribute to a better water utilization and management by the industrial sector.

2.1 Industrial Water Management

Better water utilization can be achieved through close coordination and cooperation between the water producers (water authority) and the industries that consume the water. The governmental agencies should promote and facilitate this cooperation with the industry. The prime objective of this interaction should be the optimization of the kingdom overall water utilization. Some of the promoting procedures are the following:

2.1.1 Public Awareness

Public awareness of the importance of enhanced water utilization assists in improving the country's water utilization. Awareness should not be limited to the public, but also should include the national water resources authorities. Water in Saudi Arabia is controlled directly and indirectly by three agencies:

1- Saline Water Conversion Corporation (SWCC): produces desalinated water.
2- Water and Sewage Authority (WASA): distributes water and collects treated wastewater.
3- Ministry of Agriculture and Water: supplies water to some towns and issues permits for farm wells.

Beside these agencies, there are five parties who can strongly influence the kingdom water balance positively or negatively. These are:

1- The public: Public consumption is measured by rate per capita (CRPC). The CRPC for all cities and towns are recorded and monitored for planning and control purposes.

2- The industrial sector. The industrial sector is a major consumer of water. It can contribute to the local water supply, for example, by utilizing excess heat for water desalination. In addition, the industrial sector can reuse wastewater and reduce the overall water consumption.

3- Private water suppliers: Although private suppliers provide water at higher cost, they contribute to reducing the gap between supply and demand of water.

4- Wastewater treatment providers: Wastewater treatment plants produce water of different levels of purity that can be reused in different applications. In addition, wastewater treatment reduces waste disposal to the environment.

5- Agricultural sector: Emphasizing and developing agricultural products that have lower water demand can contribute to saving water. In addition, different classes of plants can tolerate different levels of water purity. Consequently, drainage from one plantation can be used for irrigating a more salt tolerant plant.

Therefore, the country should have a planning and regulatory agency that reviews the current water practices and put the general guideline for better water management amongst all producers and consumers. It should also smoothen the relation and the coordination between all water suppliers and consumers. The regulatory authority should establish guidelines for water consumption for each industry.

For instance, it is not uncommon to find a desalination plant, a power plant, and other industrial facilities that produce their own power and water all located in the same geographical neighborhood. The lack of coordination between these parties is a major source of waste (both water and energy). A good example of this situation is the city of Rabigh. The awareness of the need of water conservation and the requirement for proper coordination between all involved parties forms the basis for the rest of this paper. The recommended suggestions, included in this paper, for better Saudi industrial water utilization, are easy to apply since industries are confined to dedicated industrial cities.

2.1.2 Water Prices

During the past fifty years numerous economic, demographic, social and environmental factors have produced dynamics in water cost and its pricing policy [Sethna, 1995, Adil, 1997]. Wastewater can provide a significant alternative source for industrial, irrigation, and

ground water recharge purposes. At least for the industrial purposes, there should be a variety of water resources as listed above. These resources will have different costs. As the industries are located in dedicated industrial zones, the different prices concept for water of different quality can be materialized, specially, if the generated wastewater streams from these industries are also valued based on the level of contamination. A wastewater stream from one industry can be utilized as feed to another industry as will be seen in the next section. Therefore, bearing in mind the different cost rates for different water qualities would enhance the overall water utilization for any industrial city. The drawback of this concept is the difficulty to construct many pipeline networks. However, the concept can be applied on limited number of resources and the industries can be promoted to establish water exchange among them. With proper planning and coordination wastewater can become a source of income instead of being a heavy liability.

2.2 Industrial Integration

Industrial integration involves improving water utilization within the same or across different industries. For instance, wastewater from one industry can satisfy the water requirements of another. Figure 1 (A and B) illustrate the concept of integration for water utilization. Moreover, arranging two different processes or industries in an integrated single process may enhance water utilization. Some of the integration techniques are the following:

2.2.1 Co-generation

Conventional power plants emit huge amounts of energy to the environment through the cycle's cooling stage. As a result, even the best combined-cycle gas turbine (CCGT) stations have overall thermal efficiencies of less than 50% [Griffiths, 1996]. For steam power cycles, the wasted energy is due to the fact that low pressure steam downstream of turbine has to be condensed and sent back to boiler before the cycle can be completed. Figure 2 shows a brief energy balance. From this figure it is clear that 65% of the total input energy is rejected to the environment through the condensation process [Al-Khaldi et. al, 1999]. The same principle applies for other types of fossil power generators, such as gas-turbines and combustion engines. Moreover, most of the desalination plants in the Gulf Cooperation Council (GCC) are dual purpose cogeneration plants. In these plants, the electricity is generated first and then the turbine exhaust low pressure steam is used in the desalination processes.

Therefore, the existing power plants can be considered for all new future expansion in desalination plants. This integration would not save in fuel cost only, but will reduce the capital, operation and maintenance cost resulting in reducing the water and power production costs. Saline Water Conversion Corporation (SWCC) is currently building an integrated power and desalination plant, but in this paper the objective is to consider utilizing the existing Saudi Electrical Company (SEC) currently operating at the Eastern and Western coasts of Saudi Arabia.

2.2.2 Extended Wastewater Utilization

Based on the water quality requirement of each industry, the wastewater from one industry can be utilized as good feed water for another industry that requires lower quality water.

Extended wastewater utilization can be applied for processes that do not change the original water quality. For instance, in some industries, the majority of feed water is used for cooling purposes. These industries have two choices:

- Build air cooled system
- Build water cooling towers

The air cooled system requires no water, however, it is more costly for large scale cooling systems since the air has significantly lower heat transfer coefficient compared to water. The cooling tower systems use cooling water and produce concentrated blow down from these cooling towers.

If industries can be integrated, then a once though cooling system can be used. In the once through cooling system, the hot water from the first industry will be used in another industry where the water temperature is immaterial. See Figure 3 for more illustration of this proposed method.

2.3 Centralized Treatment Facilities

Management coordination between industries can be used to minimize the wastewater treatment cost required for each industry.

2.3.1 Common Treatment Plants

More than one industry can share one common wastewater treatment plant. The treatment can be carried out by one of these industries or can be carried out by a separate firm specialized in wastewater treatment. Some or all of the contributing industries can utilize the treated waste streams at different level of treatment. Figure 4 illustrates this principle.

The principle of sharing common treatment facilities can also be applied to clean water production. There are many water treatment methods depending on:

- Raw water quality
- Product water quality output
- Size of the treatment plant
- Available source of energy

Based on the above, the required water treatment can vary from simple treatment by filtration and softening to more advanced desalting technologies, for example, ion exchange, reverse osmosis, and thermal desalination. Table 1 provides a general summary of the possible use for each type of raw water.

Table 1: summary of the possible use for each type of raw water

Type of water	Seawater	Treated wastewater	Desalinated water	Groundwater
Firewater	X	X	X	X
Boiler Feed Water	-	X	X	-
Cooling Water	X	X	X	X
Potable Water	-	-	X	X
Utility Water	X	-	X	X
Irrigation	-	X	X	X

2.3.2 Build, Own, and Operate (BOO) arrangement

The trend today, is toward utilizing Build, Own, and Operate (BOO) contracts for non-core business activities. By the BOO arrangement, a firm that is specialized in wastewater treatment can build its own plant to receive and treat the wastewater generated by a certain industry, or many industries and charge the industry per volume of wastewater treated. The wastewater treatment firm will have the opportunity to resell the treated water back to the same industry or to different customers. The advantages of BOO for industries are:

- Save in wastewater treatment capital and operating cost
- Provide specialization
- Enhance treatment
- Provide more flexibility for water reuse.

2.3.3 Utilizing Existing Wastewater Treatment Plants

Industries can utilize existing wastewater treatment plants to treat their wastewater effluent. This would increase the overall country water conservation, since there is a national plan to reuse the treated wastewater produced by these large wastewater treatment plants. Both sanitary and industrial wastewater treatment plants can be used for this purpose. However, the following must be considered:

- Marginal Cost: Combining an individual wastewater stream of a specific industry might increase the total cost of the whole treatment process significantly. Therefore, the marginal cost contribution of each industry should be considered.

- Selective treatment: The wastewater stream produced by one industry differs in chemical and physical properties from that produced by another industry. Therefore, the wastewater treatment facilities might require some modification of the existing treatment process to provide smooth and productive operation. In some cases, the industry may need to modify or add one process to selectively produce acceptable wastewater that can be treated by an existing wastewater treatment plant without major modifications.

- Pretreatment: each industry should meet the wastewater inflow requirements set by the wastewater treatment plant. For instance, to treat industrial wastewater by an existing sanitary wastewater treatment plant, the industry should meet the allowed limits for the hydrocarbons and heavy metal contents.

Industries that already receive water from sanitary wastewater treatment plants can return the wastewater to the same wastewater treatment plant provided that the industry treats its wastewater to a level acceptable by the wastewater treatment plant. Flow back to the wastewater treatment plant can be achieved by one of the following methods:

1. a new pipeline,
2. truck the wastewater in small quantities, and
3. utilize the incoming feed line in both directions by reversing the flow if the plant reserve allows this operation

2.4 Higher Water Recovery

Industries should be encouraged to achieve high water recovery rates, or in other words, high raw water utilization. Beside the above mentioned techniques for the improved water and wastewater management, there are a number of techniques that any industry can perform to improve its local water utilization, if directed to do so. Out of these are the following:

2.4.1 High Pressure Reverse Osmosis

The industry can install a high pressure reverse osmosis pre-treatment system to treat and reclaim wastewater from different processes. The product of the new reverse osmosis system can be re-used for the same industry. This approach would increase the overall recovery of the industry.

2.4.2 Wastewater Cooling Tower.

Wastewater cooling tower is another approach to improve the industry overall water utilization. This approach can be adapted in industries that have cooling water towers. In this approach, the wastewater streams are diverted to the cooling water towers and new heat

exchangers are installed to exchange heat only between the industry and the cooling water system. This approach has two advantages: eliminate the cooling tower make up of fresh water and reduce the volume of wastewater produced.

2.4.3 Blending.

Wastewater generated at one area can be blended to produce a quality of water that is suitable for another area. Recycling is another type of blending currently utilized in almost all industries. Another example is to recycle the reject water from the second pass reverse osmosis units back to the feed of the first pass reverse osmosis units. Blending can be applied also across industries.

3. CONCLUSION

Better management of current and potential resources, better planning of future industrial projects and promoting and enforcing water conservation policies can realize better Industrial utilization of local water resources. Integration of industries can improve water utilization. Government policies can be enforced to promote water conservation by giving incentives to industries that utilize water efficiently. Customer awareness of the environmental and strategic advantages of water conservation can participate in driving the local industries towards better water utilization.

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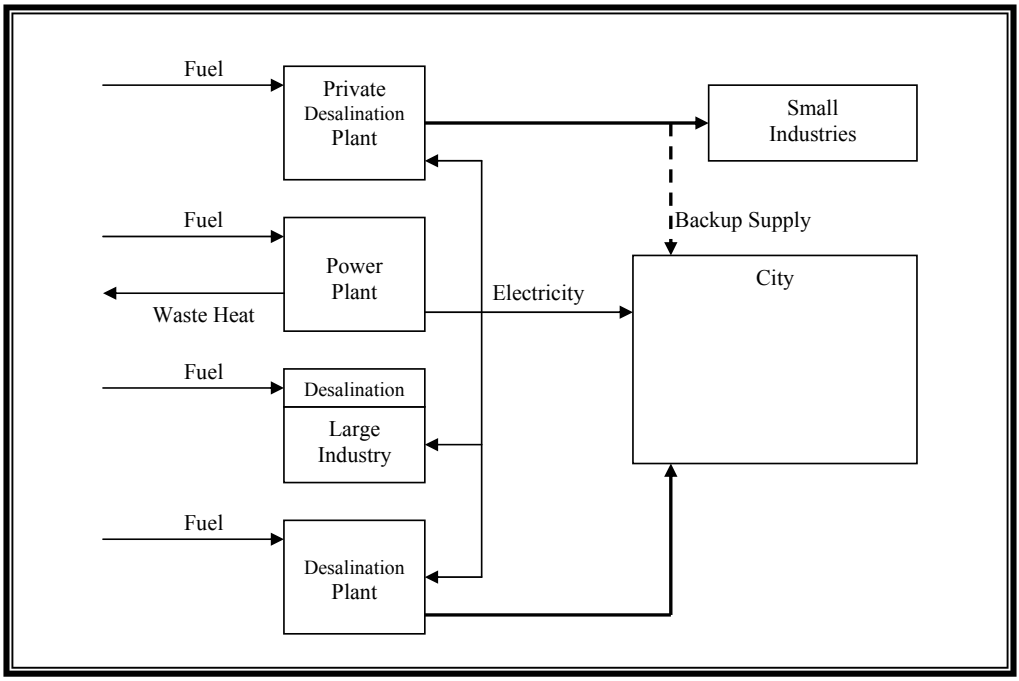

Figure-1A: imperfect Integration of Industries

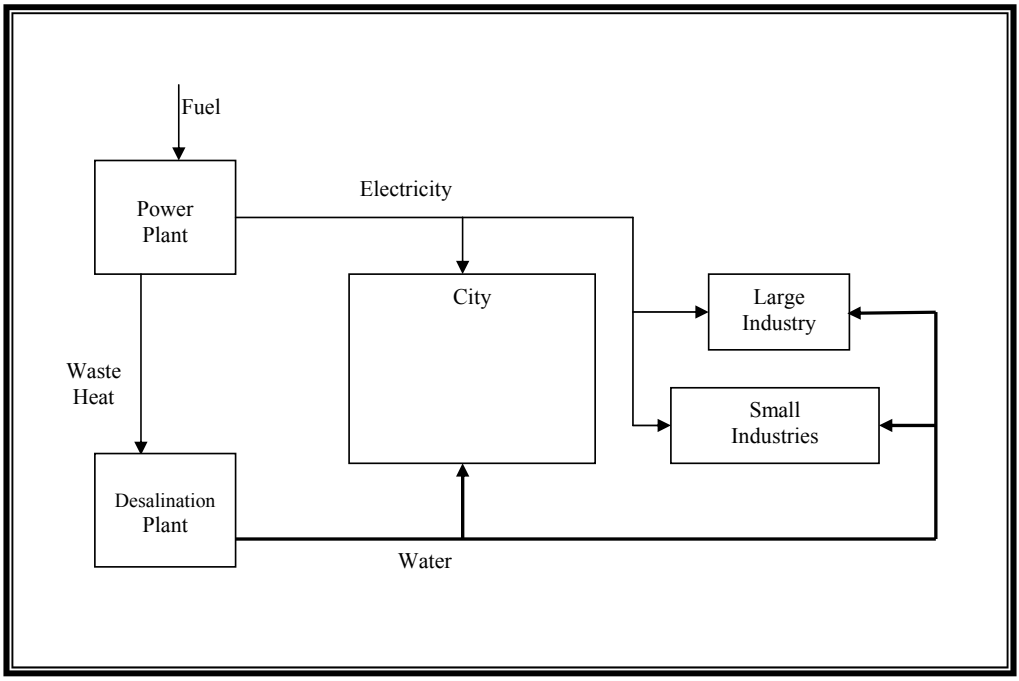

Figure-1B: Perfect Integration of Industries

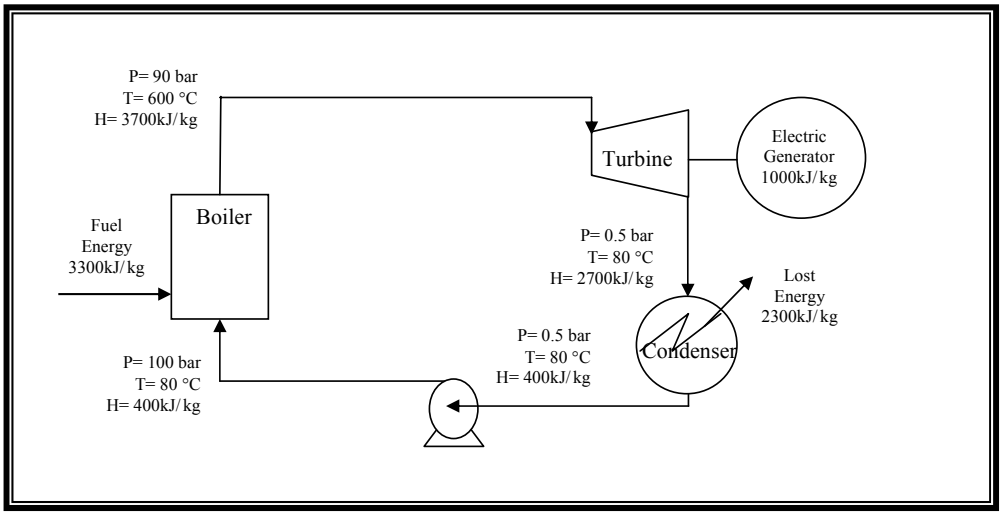

Figure-2: Cogeneration Cycle

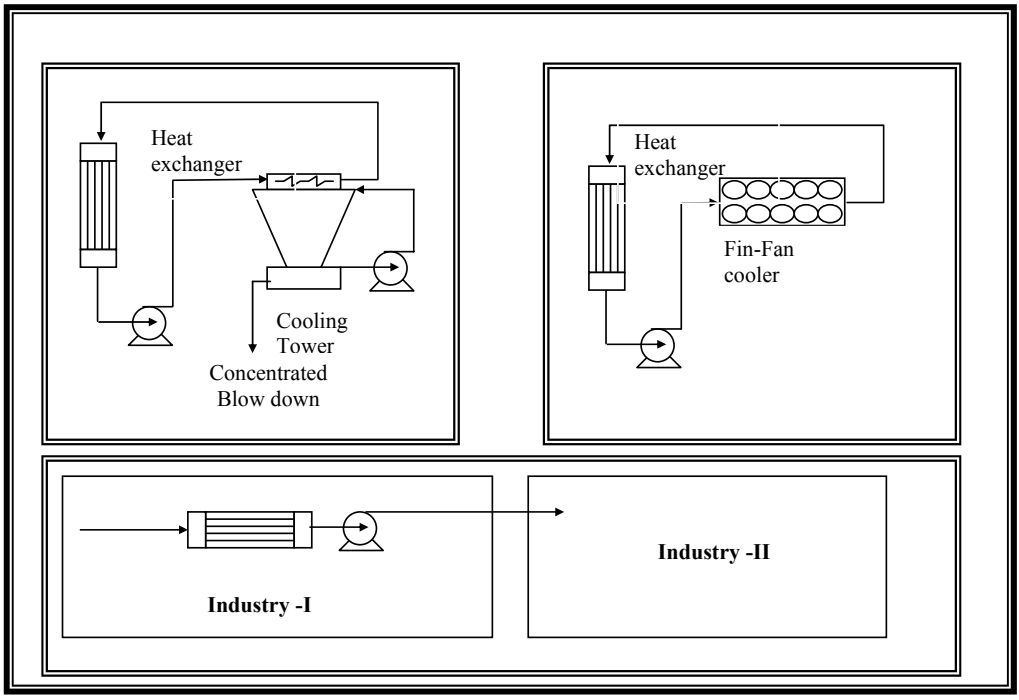

Figure-3: Once Through Cooling System

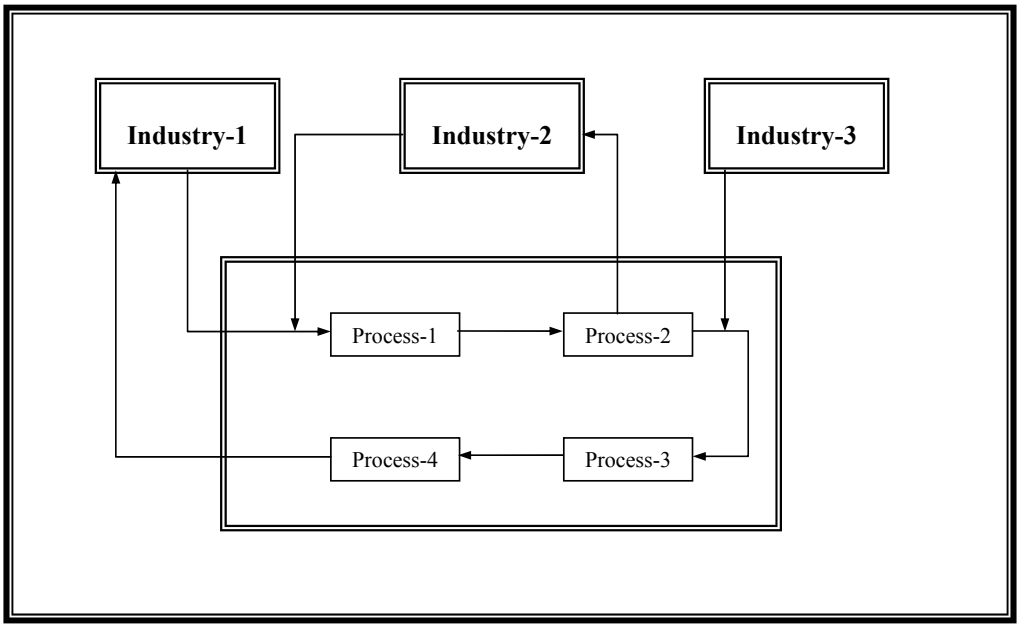

Figure-4: Centralized Wastewater Treatment System

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