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NAME: Ms. Somkid Buntatao

THIS THESIS HAS BEEN ACCEPTED BY

________________________ **THESIS ADVISOR**

(Assistant Professor Narumol Vongthanasunthorn, D.Eng.)

________________________ **THESIS CO-ADVISOR**

(Associate Professor Winai Liengcharernsit, D.Eng.)

________________________ **DEPARTMENT HEAD**

(Assistant Professor Mongkol Damrongsri, Dr.Ing.)

APPROVED BY THE GRADUATE SCHOOL ON ________________________

________________________ **DEAN**

(Associate Professor Gunjana Theeragool, D.Agr.)

THESIS

EFFECTS OF SMALL FOUNDRY INDUSTRIES TO NEARBY COMMUNITIES

SOMKID BUNTATAO

A Thesis Submitted in Partial Fulfillment of
the Requirements for the Degree of
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This research was carried out to measure the operation of Foundry Industries in Phetkasem 51 Road,Bangkok especially the air pollution system which were complaint by people since 2004 that it has emitted pollutants to atmosphere and community and at present people still complain although the related government agency has been trying to solve the problems. All air measurement in workplace (3 sites),stack and community found that a trend of pollutant has decreased from the past but the problem still exists because it is hard to predict the exact emission concentration. Because all foundry factory's spray tower are low efficiency, CO, TSP and PM-10 level in the community are over the air quality standard so installation of the pack tower is necessary for these foundry factories to prevent the further effects to community though the health risk analysis on people who might expose the pollutants revealed a small risk currently.

The research suggests 3 principle ways for the owner of foundry factory's including 1) improve the efficiency of their present air pollution control system, by maintenance annually and raise liquid to gas ratio to increase liquid pressure for more pollutant capture in gas stream. 2) redesign a new air pollution control system to be a pack column instead a spray tower since a pack column can remove SO_2 and dust in the same time but a spray tower can remove only dust 3) apply integrated strategy: clean fuel usage, tall stack, improvement of combustion process and cooperate among related group.

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Student's signature Thesis Advisor's signature

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Somkid Buntatao
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LIST OF ABBREVATIONS

ACFM	=	Actual Cubic Feet per Minute
BMA	=	Bangkok Metropolitan Administration
C	=	Carbon
CO	=	Carbon monoxide
CO_2	=	Carbon dioxide
DIW	=	Department of Industrial Work
dB(A)	=	Decibel A weighting
Dt	=	Diameter of tower
ft	=	Feet
g	=	gram
hr	=	Hour
HI	=	Hazard Index
in	=	inch
lb	=	Pound
lb/hr	=	Pound/ Hour
m^3	=	Cubic Meter
m^2	=	Square meter
Mg	=	Milligram
min	=	Minute
mm	=	Millimeter
NO_2	=	Nitrogen dioxide
O_2	=	Oxygen
PCD	=	Pollution Control Department
s	=	Second
SO_2	=	Sulfur dioxide
TSP	=	Total Suspended Particulate
WBGT	=	Wet Bulb Globe Temperature
%	=	Percent

EFFECTS OF SMALL FOUNDRY INDUSTRIES TO NEARBY COMMUNITIES

INTRODUCTION

In the past, Bangkok had no regulation to control land use. As a result many Factories are located in residential area and spread everywhere close to their resource or customers to reduce transportation cost. Presently, even though Bangkok Metropolitan Administration (BMA) has been trying to solve the problem by forcing factories, which have dominated pollution to the community to move out from crowed areas, however many factories are still located own's land areas and emit pollutants as usual. Report in 2004 by the Department of Health., BMA, informed that most of foundry factories were located in Bangkae and Jomthong Districts.The reasons are due to the following factor:

1. The lack of regulation on zoning and land use. Even though, BMA, have been enforced "Town planning Act" which started in 1974, but it could not enforce backward before the effective date therefore old factories that operate before the day could stay in old area. In some case, this plan allows the factories to locate in the residential area although it is set as green zone if the whole factories areas is not more than 10-30 percent of whole area.

2. The highly expansion rate without control. Bangkok Metropolitan is a megalopolis with an ongoing expansion physically, economically and socially. Despite the improvement in jurisdictional administrative systems, the rapid growth in economic and population resulted in consequential problems such as over-crowdedness, traffic congestion, environmental issues, slums, and insufficient infrastructure and facilities. Such problem is hard and difficult to solve without effective city planning.Even though there are agencies under the Bangkok Metropolitan Administration which responsible for preparing and making the Bangkok comprehensive plan in order to control, improve, amend and change conditions of the

city to make Bangkok a livable city. Nevertheless, the efforts and commitments made by Bangkok Metropolitan Administration could be materializing to their full potentials only when the public extends to participate and support the government sectors. Only then, problems arising from the inevitable growth and expansion of Bangkok can be solved.

3. Low efficiency air pollution control regulation. Foundry factories in Bangkok are very old and to save cost, they usually had been operated with the low technology and low efficiency air pollution control system. Worthless, some factories, some times, turned off the air pollution system that used to threat pollutant from their process. Some might did not have a good maintenance except when the checking officer visits the factory or once they needed the new permit paper.

4. Dirty fuel and incomplete burning.Since the factory owners try to save the operation cost, they selected to use low grade fuel or cheap raw material. The example is metal that contaminated with hydraulic oil and other old metal parts which caused incomplete burning in the process. Resulting,the early starting period of furnace is very crowed by smoke, covering all their workplace and spread out to nearby community for long distance. Including lack of the environmental awareness. Some factory owners did not aware about the hygiene both the environmental and workplace condition.

5. The deficient of the law enforcements and the authority. Even factory owners did not do comply the factory conditions to the regulation however,to enforce or punish them under the recent law was difficult and need a long time to complet. Because there is lot of factory types located in all 50 districts of Bangkok area, about 125 types of factories and more than 30,000 sites are in BMA responsibility.However a number of environmental officer are small number compared with a number of factories. There for BMA could not send an officer to inspect all factories frequently in and enforce the factory to obey the law

From those reasons, it results the problems consequently as below:

1. Health Impact. The surveillance of respiratory tract such as allergic and lung disease, especially occurring in sensitive people such as elderly and children. All people have health risk higher than others who live in the rural because they expose pollutants from foundry factory for long time, and they could not request any compensation from factory without the improvement that the effect are caused by unsafe factories.

2. Environment Impact. The crowded smog, especially in the morning, increases the level of Carbon Monoxide (CO), Sulfur Dioxide (SO_2), PM_{10}, to the ambient. Emission from a steel mill, foundry factories, construction and road dust are significant contributed to air pollution problem in Bangkok Metropolitan Area .SO_2 is primary pollutant which might combines with moisture in the air to form mild acids rain that fall to Earth, damaging plant, car, monuments. Otherwise CO is toxic gas can harm people and environment.

3. Socio Impact. Stress by nuisance caused by the smog, people stay in their house unhappily and inconvenience. They always close their window and cover the belonging by cloths because a lot of dust from the foundry factory. Sometime they could not stay in their house on weekend.

4. Economic Impact, caused by exhausted gas, cloths, building roof were corrosive and damaged. Some business such as condominium or house could not be sold or rent because it is unpleased to living. These pollutants also damaged the flower garden which growth for the recreation purpose also.

5. Social impact caused by the conflict and argument between the Factory owner and the community. Because people who live near the foundry factory want these foundry factory to be closed or move out to another area but it cold not be reply. There for the social relationship in the area is very poor.

OBJECTIVES

From the problems, the researcher who has been working as sanitary officer of BMA and has faced on these environment problems is interesting in study by the knowledge to know its status solution for all participants. The objectives of this study are to find out the tactics to solve the problem with will compromise all participants, the knowledge and reasonable technique and cost for factory owner. Later it could be present to BMA for set up environment Policy of Bangkok, at least, this main purpose will success the study design specific objective are this below

1. To study the efficiency of air pollution control system in foundry factories in the study area.

2. To find the resolution on air pollution control system.

Scope of the study

1. To study the air pollution system on 11 factory sites in Phetkasem Soi 51 Road, Bangkare, Bangkok. which used cupola furnace and for aluminum cast in Table 1

2. To study the pollutants condition released from the factories to the nearby community.

3. To study the ambient air conditions on the community in Phetkasem Soi 51 Road, Bangkare ,Bangkok. The radius area that might has the impact and also the resolution in case of highly toxic gases level releases and resolution.

Table 1 Location and factory Identities in Petkasem Soi 51 Road Bangkare, Bangkok.

Order	Suppose Name	Product	Engine power (horsepower)	Worker (person)
1.	B.	Water work equipment	543.45	13
2.	Y.	Engine parts ,Auto parts	200.00	7
3.	T.	Gears	269.90	10
4.	U.	Engine parts	73.00	7
5.	K.	Engine parts	274.00	10
6.	TP.	Wheel	7.65	6
7.	LH.	Agriculture machine balls	73.91	5
8.	TT.	Coupling valve	443.00	24
9.	TN.	Iron cast	396.85	10
10.	HS.	Engine parts	56.00	5
11.	KD.	Buddha Image cast	-	20

Source: Heath Department, BMA (2004)

LITERATURE REVIEW

1. Foundry Industry in Bangkok

1.1 Distribution of Foundry Factories

According to the Public Health Act B.E. 2535, the definition of industrial factory is "the business detrimental to health". In Bangkok, foundry industry is one type of industry which must have the permission from BMA. At present, there are 389 foundry factories located in Bangkok. Though BMA has issued a strict rule which does not give a permission to install new foundry factories in Bangkok, there are still some illegal small foundry factories spread on many parts of Bangkok. Most foundry factories are located in the uptown areas of Bangkok, such as in Chomthong District, Prawet District, Tungkru District and Bangkhae District, whereas in the inner Bangkok area, the preserve culture zone, such as in Dusit District and Pranakorn District is no foundry factory (Table 2 shows the distribution of foundry factories in Bangkok). These factories have caused some nuisance problems and complaints from nearby residents many times. In 2007, there are 25 cases (out of a total 115 cases) reported to BMA, mostly from Sampantawong District where there are some small gold melting household factories.

Table 2 Distribution of foundry factories in Bangkok

Oder	District	Total number of foundry factories
1.	Bangkhae	119
2.	Chomthong	39
3.	Bangrak	35
4.	Tungkru	18
5.	Ratburana	16
6.	Bangbon	13
7.	Sampantawong	12

Source: Health Department, BMA (2006)

1.2 Nuisance Problems due to Foundry Factories

The nuisance problems from foundry factories in Bangkok which the Environmental Sanitation Division, BMA has inspected and monitored according to the Public Health Act are mainly due to emission of exhausted gases which contain high concentrations of air pollutants (total particulate matter, carbon monoxide, sulfur dioxide, etc.). Noise from some factories also causes nuisance problem. Moreover, there are government agencies, including Department of Industrial Works (DIW), Pollution Control Department (PCD), Bangkok Metropolitan Administration (BMA), which had been trying to enforce these factories to improve their manufacturing and pollution control processes. However, there were some complaints from nearby residents. The BMA also set up a meeting of 3 parties included the involved government agencies, manufacture enterprise and local residents (Figure1), but there was limited interest from the manufacture enterprise and the government agency has limit budget to conduct this kind of meeting for regularly.

Figure1 Meeting among three parties

Source: Health Department, BMA (2006)

1.3 Classification of Foundry Factories

Foundry factories in Bangkok could be classified, based on type of melted materials, into 2 groups included ferrous and nonferrous. The nonferrous group is mainly aluminum factories which produces aluminum products or recycle aluminum from scrap.. Figure 2 shows the classification of materials mentioned above.

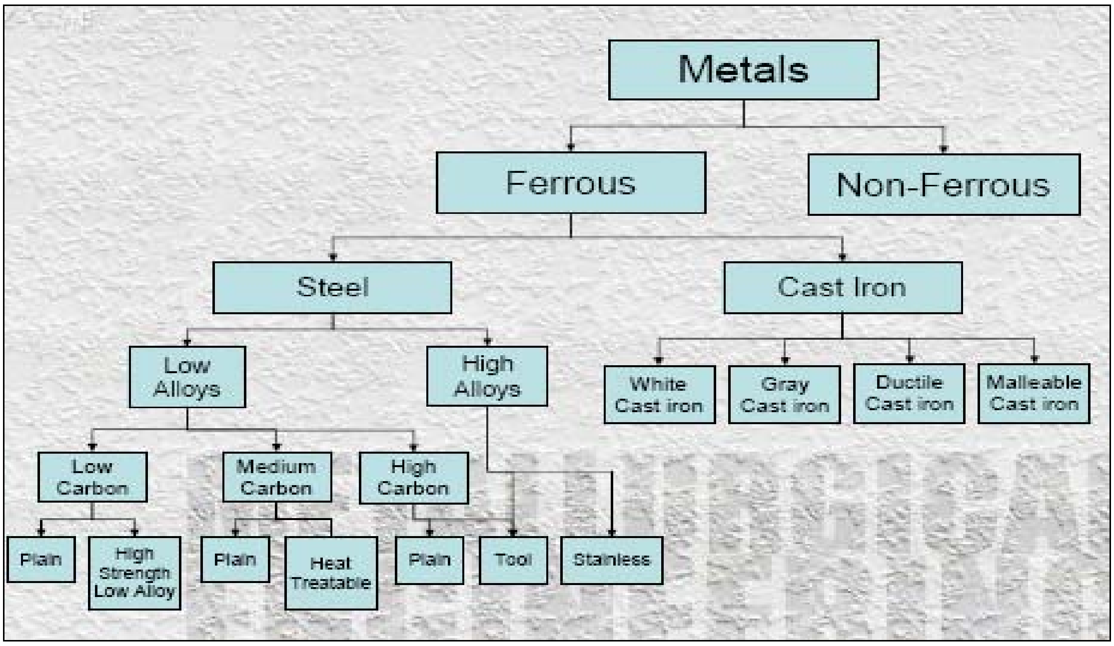


Figure 2 Classification of material
Source: Suranaree University of Technology (2007)

Foundry factories in Bangkok are mostly low capacity factories. The product quality varies depending on customer need. Most of them, 90 %, are in the ferrous group, either cast iron or steel. The cast iron is majority because it not complicated. The main products are gray cast iron. On the minority, the steel group is the factory which can produce high standard steel products for exportation. The remaining 10% is the non-ferrous group that produces aluminum, copper, and lead.

1.4 Properties of Cast Iron

There are some different types of iron material, including gray cast iron, ductile cast iron, white cast iron, and malleable cast iron. Figures 3 and 4 show the structures of this cast iron.

Gray Cast iron contains between 2.5–4 % of carbons. It has high hardness. The basic composition is ferrite or pearlite and its microstructure is flake graphite. The name “Gray Cast iron White” comes from the sprite of cast iron which is gray in color.

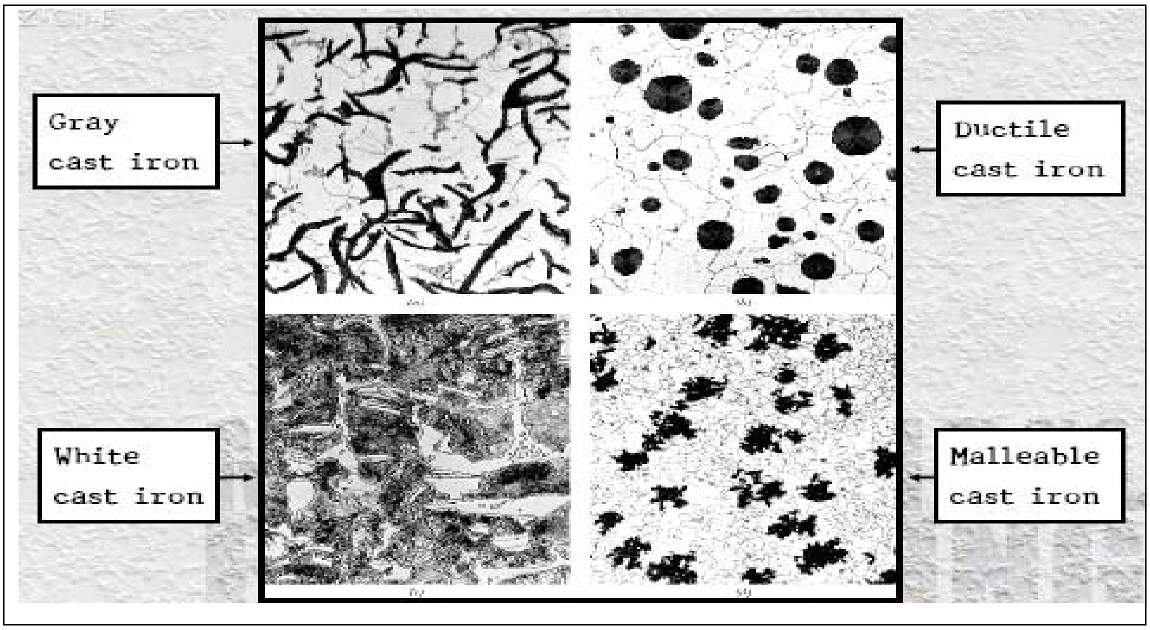


Figure 3 Structure of Cast Iron

Source: Suranaree University of Technology (2007)

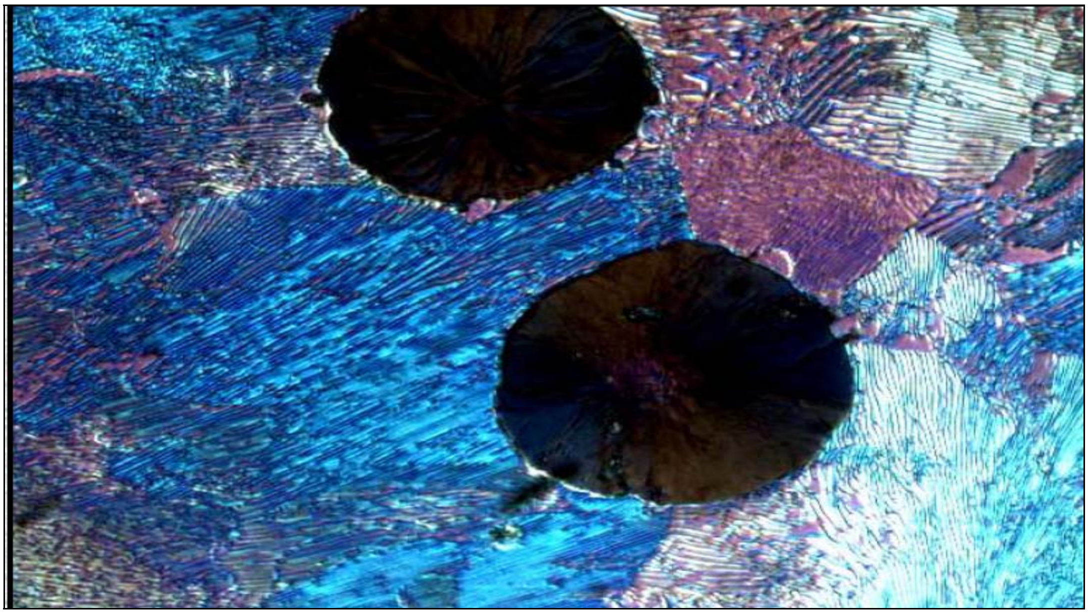


Figure 4 Microstructure of Ductile Cast Iron
Source: Suranaree University of Technology (2007)

Ductile cast iron made of adding Mg or Ge in gray cast iron during melting process, consequently graphite will be changed into circle shape. Its microstructure is modular graphite and basic composition is ferrite or pearlite.

White cast iron contains less than 1% of Si and was reduced its temperature immediately. The composition is Carbon in Fe_3C form which hard and high corrosion resistance.but easy to break it down and less resistance from impaction

Malleable cast iron is occurred from roast White cast iron process at temperature 800-900 ^{o}C with more than 30 minutes in close system. Fe_3C will be broken and graphite occurs in flower shape, high tensile strength and to be drawn, stretched or formed without breaking.

1.5 Foundry Process

Conventional foundry processes are molding and melting. Firstly, raw metal is poured into the mold and clean casting, sand conditioning to reuse. Type of sand casting is majority. Mold are several type, general mold in foundry factories are green sand mold, skin dried mold, dry sand mold ,loam mold, furan mold, CO_2 mold, metal mold and special mold. But in commercial way of molding procedure are classified in many types like floor molding, bench molding, pit molding and machine molding. Later, there are permanent mold because sand casting must break mold when bring a work piece from mold. These special casting are casting in metallic mold, centrifugal casting, precision and investment casting and continuous casting. The unit in process of molding, special foundry process and simply process shown in this below:

1. Sand Muller and conditioner
2. Sand storage
3. Sand distribution belt
4. Sand hopper for each molding machine
5. Molding machine
6. Pouring area
7. Conveyor
8. Mold cooling and gas disposal
9. Shake out
10. Magnetic separator
11. Centrifugal casting
12. Die casting
13. Casting in metallic mold
14. Low pressure
15. Slush

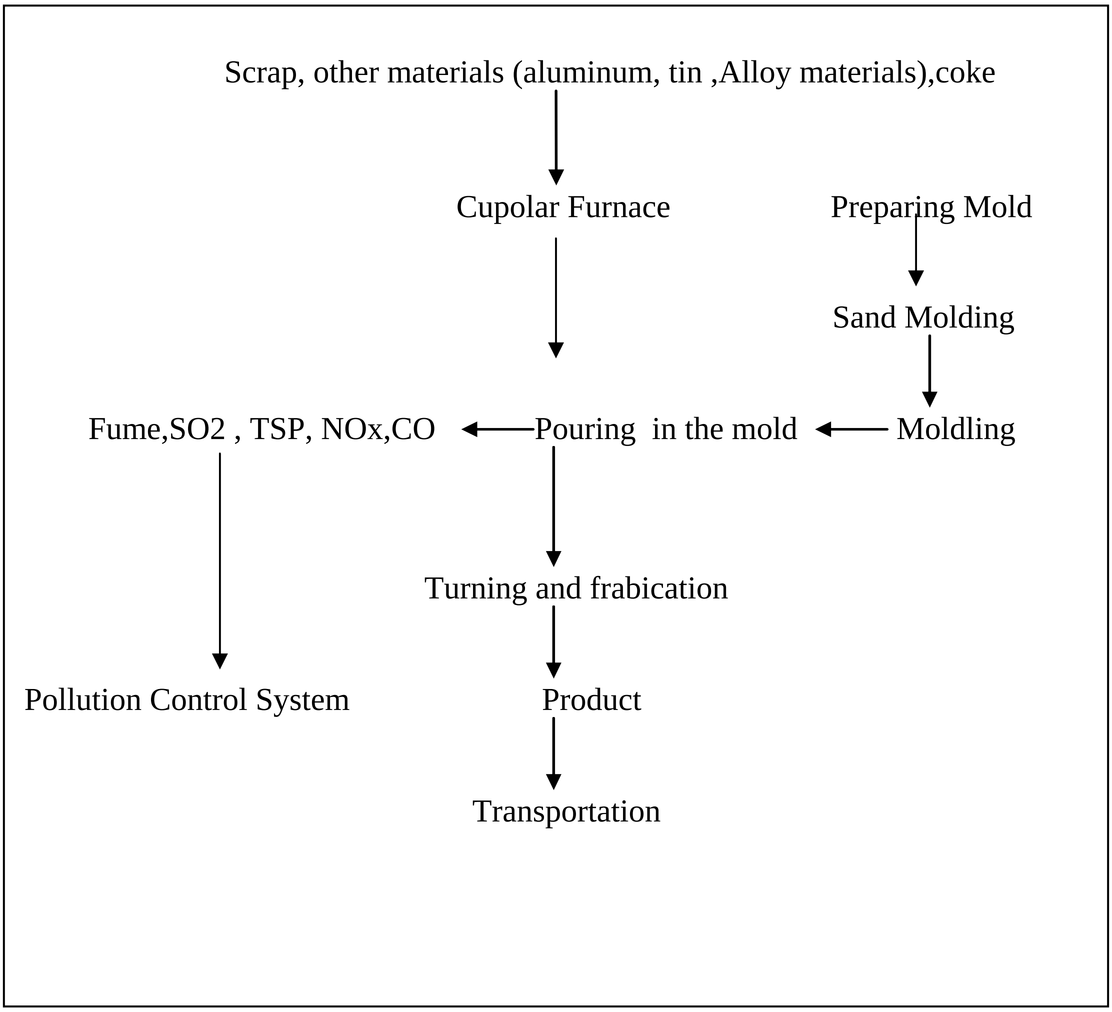


Figure 5 A conventional foundry's process

Source: Tawee (1997)

1.6 Furnaces type

Furnace for Converting Pit Iron. Generally pit iron was melted in permanent mold or transferred while melting from hot ladle car to furnace and then form wrought iron ,steel, cast iron ,ductile iron or malleable iron.

1. Basic Oxygen Furnace (BOF). Basically, main raw material is pig iron from blast furnace about 65-80% and other raw material are scrap and limestone. Heat

is came from spraying oxygen into furnace, some furnace spray air in down side of furnace instead oxygen called, Bessemer Converter, but it does not popular.

2. Electric Furnace, using steel which was screen first sometime it use molten pig iron but need to check the process closely. This furnace has 2 types, indirect arc furnace and direct arc furnace. The advantage of Electric Furnace is friendly to the environment

3. Open–Hearth Furnace, it was popular in the past but recently is decreased. It is reverberated furnace. Heat come from gas, tar burning or use oil spray through out metal will be in bowl which is not deep ,there are regenerative with 2 chambers in both side of furnace

4. Cupola is popular in industrial foundry because it is simply to construct and could work continuously for long time, high capacity. The structure of cupola are included: Main body which made of steel, lining fill with high fire resistive brick (tracle brick) or chamotle, Charging door for fill metal and coke,Tuyers for wind blowing,Tap hole is the bottom of cupola for drain slag and Window box

Melting in Cupola, there are 2 reaction from tuyers to bottom of cupola, coke was burned at high temperature (reaction 1). And at the top of cupola is reducing reaction, CO_2 change to CO (reaction 2). The rate of reaction depend on volume of O_2 , size of coke, hole size and other factors. Melting capacity relative with diameter of cupola shown in table 3 and several type of furnace show in table 4

$$C + O_2 \longrightarrow CO_2 \qquad (1)$$

$$CO_2 + C \longrightarrow 2CO_2 \qquad (2)$$

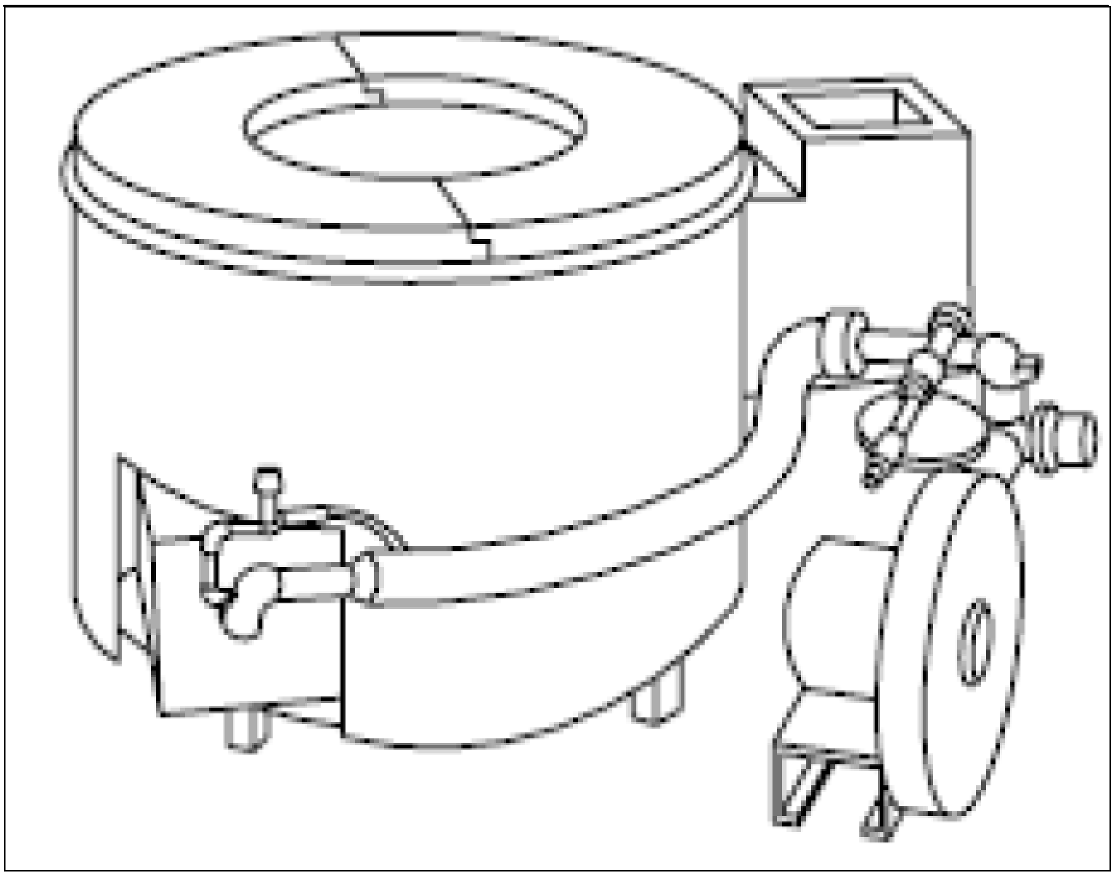


Figure 6 Crucible Furnace

Source: Suranaree University of Technology (2007)

Table 3 Relationship between diameter of cupola and melting rate

Diameter (mm)	Area (m^2)	Melting rate (ton/hr.)					
		Ratio between coke and steel (%)					
300	0.071	0.74	0.64	0.57	0.52	0.47	0.42
350	0.096	1.0	0.9	0.8	0.7	0.67	0.58
400	0.126	1.3	1.1	1.0	0.9	0.83	0.76
450	0.159	1.7	1.4	1.3	1.2	1.05	0.95
500	0.196	2.1	1.8	1.6	1.4	1.3	1.2
550	0.238	2.5	2.2	1.9	1.7	1.6	1.4
600	0.283	3.0	2.6	2.3	2.1	1.9	1.7

Table 3 (Continued)

Diameter (mm)	Area (m2)	Melting rate (ton/hr.)					
		Ratio between coke and steel (%)					
650	0.332	3.5	3.0	2.7	2.4	2.2	2.0
700	0.385	4.1	3.5	3.1	2.8	2.6	2.3
750	0.442	4.7	4.0	3.6	3.3	2.9	2.7
800	0.503	5.3	4.6	4.1	3.7	3.3	3.0
850	0.567	6.0	5.2	4.6	4.2	3.8	3.4
900	0.636	6.7	5.8	5.2	4.7	4.2	3.8
950	0.709	7.5	6.4	5.8	5.2	4.7	4.3
1000	0.785	8.3	7.1	6.4	5.8	5.2	4.7
1050	0.866	9.2	7.9	7.0	6.3	5.7	5.2
1100	0.950	10.0	8.6	7.7	7.0	6.3	5.7
1150	1.039	11.0	9.5	8.4	7.6	6.9	6.3
1200	1.131	12.0	10.3	9.2	8.3	7.5	6.8
1250	1.227	13.0	11.2	10.0	9.0	8.1	7.4
1300	1.327	14.0	12.1	10.8	9.7	8.8	8.0
1350	1.431	15.1	13.0	11.6	10.5	9.5	8.6
1400	1.539	16.3	14.0	12.5	11.3	10.2	9.3
1450	1.651	17.5	15.0	13.4	12.1	11.0	10.0
1500	1.767	18.7	16.1	14.3	13.0	11.7	10.6

Source: Tawee (1997)

Table 4 Several types of furnace

Type of furnace	Primary Fuel	Predominate Metal Charge	Product
Air or reverberate	Pulverized coal, oil	Molten or solid pig iron scrap	Gray cast iron, White cast iron
Basic oxygen	Oxygen	Molten pig iron and scrap	Steel
Converter	Air	Molten pig iron or molten copular iron	Raw material for wrought iron and steel
Crusible	Gas,coke, oil	Select scrap	Small quality of steel and cast irons
Cupola	Coke	Solid pig iron and scrap	Gray cast iron , Nodular iron
Electric furnace	Electricity	Scrap	Steel, gray iron
Induction	Electricity	Select scrap	Steel
Open–hearth furnace	Natural gas, coke oven gas, pulverized coal ,oil	Molten pig iron	Steel

Source: Tawee (1997)

In Bangkok most of foundry factories have used cupola about 60 % , small crucible about 20 % ,electric furnace about 10 % and other furnace about 10 % .Their furnace are very old and mostly are small size ,some factories have used 2 furnaces in same workplace. Basically, they will not operate every day, it depend on customer‘s order. Most of small factory always work 2-3 days a week,except the high capacity factory that will work continuously 6 day in one week.

Figure 7 Cupola in small foundry factory in Bangkok area

1.7 Fuel Types

Solid fuel, mention to fuel in solid form at normal temperature ,solid fuel are from natural such as wood ,glass, coal, Oil Shale. Solid fuel from manufacturing such as Charcoal , coke, fuel briquette ,lignite semi-coke .The composition of solid fuel are ash which form by inorganic substance and water and other substances. Basically, foundry factories use coal ,a natural solid combustible material formed from prehistoric plant life. It is too high in sulfur content to meet desirable pollution standards unless sulfur is removed by scrubbing. Chemically coal is a macromolecular network comprise of groups of poly-nuclear aromatic rings, to which are attached subordinate ring connected by oxygen, sulfur, and aliphatic bridges. This extended open structure is conducive to catalytic reaction, which in effect subdivide it into smaller molecules that can be refined readily. Classification of coal is Peat, Lignite, Bituminous, Anthracite (hard coal)

Coke, the carbonaceous residual of the destructive distillation (carbonization) of bituminous coal, petroleum, and coal-tar pitch. The principal type is that produced by heating bituminous coal, petroleum, and coal tar pitch. Heating bituminous coal in chemical recovery of beehive coke ovens (metallurgical coke), from a ton of coal yield approximately 0.7 ton of coke. It is use chiefly for reduction of iron ore in blast furnaces, and as a source of synthesis gas. Petroleum yield coke during the cracking process. Coke from petroleum residual and coal –tar pitch is use for refractory furnace linings in the electro-refining of aluminum and other high temperature service, and for electrodes in electro-thermal production of Al_2O_3 to aluminum, as well as in electro-thermal production of phosphorus, silicon carbide, and calcium carbide.

Figure 8 Fuel and raw materials in foundry factory

1.8 Pollutants emitted from Foundry Factories

There are many pollutants from foundry factory affected to several things Such as the environment and health. In this part will mention the pollutants affected to health detailed as below

Carbon monoxide (CO),Carbon monoxide‘s properties are colorless gas or liquid, practically odorless, burn with a violet flame, slightly soluble in water, soluble in alcohol and benzene. Density is 0.96716, bp -190 °C , freezing point -207 °C specific volume 138 Cu ft/lb. Auto ignition Temperature (liquid) 1128 ° F. Classed as an inorganic compound. Carbon monoxide has an affinity for blood hemoglobin over 200 times that oxygen is. It is a major air pollutant. Toxic by inhalation on TLV is 50 ppm a symptom is sleepy and made difficult to breath.

Nitrogen dioxide (NO_2),Nitrogen oxides in the atmosphere are three oxides of nitrogen. Including nitrous oxide (N_2O), nitric oxide (NO), and nitrogen dioxide (NO_2) Microbial generated nitrous oxide is relatively non-reactive and probably does not significantly influence important chemical reactions in the lower atmosphere. Its concentration decrease rapidly with attitude in the stratosphere due to photochemical reaction,properties of Nitrogen oxides colorless, odorless, nitric oxide (NO) and pungent red–brown nitrogen dioxide (NO_2) are very important in air.

Sulfur dioxide (SO_2) also “Sulphur dioxide” A colorless gas with a Pungent odor. If the gas dissolves in water, sulphurous acid is formed. Sulphur dioxide leaks constitute a serious threat to the environment, as sulphur dioxide is transformed into sulphurous acid with acidifies lakes and streams. Contact between Sulphur dioxides may cause explosive substance to form. The major sources of sulfur dioxide are fuel combustion, industrial processes and transportation. Combustion of fossil fuels for generation of electric power is clearly the primary contributor of sulfur dioxide emissions. Industrial processes such as Smelting of sulphide ores (copper, zince, lead, nickel also contribute to sulfur dioxide emissions and other process, roasting, converting.Overall (Roasting or smelting or converting)

$$CuFe\ S_2 + O_2 \longrightarrow Cu + Fe + SO_2 \qquad (3)$$

Once released to the atmosphere, sulfur dioxide reacts slowly to form sulfuric acid (H_2SO_4) .Some of the sulfur dioxide in high temperature process is oxidized to form sulfur trioxide as show below

$$SO_2 + ½\ O_2 \longrightarrow SO_3 \qquad (4)$$

Sulfur trioxide remains in the vapor state while the combustion gases are very hot. As the gases cool, Sulfur trioxide adds a water molecule and forms sulfuric acid as indicated by the reaction below

$$SO_3 + H_2O \longrightarrow H_2SO_4 \qquad (5)$$

Sulfuric vapor in moderate concentration is very beneficial to Electrostatic precipitator because it adsorbs onto particle surfaces and creates a moderate resistively. High concentrations can be detrimental to precipitator performance. High sulfuric acid levels can also cause significant corrosion problem for precipitators, fabric filters, and other control devices. The temperature of flue gases should be kept well above the dew point for sulfuric acid to prevent condensation on ductwork surfaces and components in the air pollution control system.

Harmful effect, when sulfur dioxide is combined with the humidity in the eyes and the mucous membranes of air passage, sulfuric acid is formed, a substance with a highly irritating and cauterized effects. Sulfur dioxide which has been sucked up by cloth and mixed with water cauterizes the skin as well.

High concentration of sulfur dioxide may cause fatal lung injuries because of highly these type lung injuries. Consequently, the risk of pulmonary edema is especially high when people are locked up or if the escape route is long.

Inhalation of sulfur dioxide for extended period of time may cause increased formation of mucous in the air passage as well as tracheal catarrh. The effects of sulfur dioxide are usually aggravated by the simultaneous present of certain other substances, e.g. soot particle and ozone.

Suspicions have been aired that sulfur dioxide may be carcinogenic. There is nothing indicating that sulfur oxide by itself may cause cancer in man, however. On the other hand, it is possible that of presence of sulfur dioxide may intensify the carcinogenic effect to other substances.

Particulate, there are 2 categories of particulate which major effect to health and PM_{10} and $PM_{2.5}$. There adverse health affects usually associated with small particle (less than 10 micron) can be attributed to their ability to upper respiratory tract, there chemical composition and there has an ability to remain air born for long time. The respiratory system may be damaged directly by particulate maters that enter the blood system or lymph system through the lungs. In addition, the soluble components of the particulate material may be transported to organs. Dust from production process occurs from 2 steps, firstly dust emission which collect and remove out at forth roof whole, secondly dust emission.

Global warming effect, CO_2 is one of greenhouse gases from foundry process cause global warming ,fuel burning (coal) will emit CO_2 and waste water from these foundry factories will emit CH_4 gas which increase global warming problem in high level like other manufacturing industries which never control CO_2 gas because they are old technology and don not relies about environment. In table7 shows Greenhouse Gases (GHGs) and Global Warming Potential (GWP),six greenhouse gases are not equal in terms of global warming potential,which measures the relative effect of (GHGs) compared to CO_2

Table 5 Greenhouse Gases (GHGs) and Global Warming Potential (GWP)

Greenhouse Gases (GHGs)	Global Warming Potential (GWP)
Carbon Dioxide (CO_2)	1
Methane (CH_4)	21
Nitrous Oxide (N_2O)	310
Hydrofluorocarbons(HFCs)	140-11,700
Perfluorocarbons (PFCs)	6,500 – 9,200
Sulfur Hexafluoride (SF_6)	23,900

Source: Prasit Vaiyavatjamai,lecture seminar class (2007)

Figure 9 The work place environment

Liquid waste from air pollution control system, wet scrubber circulate liquid was contaminated of SO_2 mixed with water occur H_2SO_4 and some particulate from burning and melting process. In fact manufacture usually reuse water circulate in many times without treatment there for water cause obstruction of wet scrubber and sometime they drain waste water to environmental.

Noise, in foundry factories there are high sound level causes noise problem for worker who works in workplace without properly personal protection equipment (PPE), reported by Environmental Sanitation Division, BMA (2007) found 100% of worker in 40 foundry factories never ware properly personal protective equipments.

Other pollution which effect health are fume and heat in workplace the temperature rather high worker risk to heat stroke and weak, accident from melted metal, failed and air born disease

Solid waste, sludge waste, slag is the dross of flux and impurities that rise to the surface molten metal during melting and refining. There are many type of slag and have different property depend on melting process ,scrap melting in Electric Arc Furnace occur calcium silicate slag different from slag in desulphurization of steel, ladle slag and AOD slag. Chemical properties of slag show in table 6

Most of all foundry factories in Bangkok have used wet scrubber, but manufacturers familiar with other name such as spray tower, dust collection tower and others. In each factory have same wet scrubber but different in accessories which ensure those that the pollution control system can treat emission from their process. The problems about the pollution control system are maintenance, criteria design, capacity loading and the budget

In Bangkhae District there are 119 factories, reported by Environment Sanitation Division, 110 factories have used wet scrubber and the rest have used other system which can not identify.

Table 6 Chemical properties of slag

Components (%)	Process		
	BOF	EAF	AOD
CaO	50	35	53
SiO_2	15	15	28
$Al_2 O_3$	≤2	6	3
Mg O	≤ 3	8	5
Fe_{tot}	16	18	≤2
Fe_{met}	≤1	≤1	≤1
MnO	≤4	5	≤1
P_2O_5	≤2	≤1	≤0.5
Cr_2O_3	≤1	≤1	≤2
CaO_{ft}	-	-	≤1
CaO/SiO_2	≤2.5	≤2	≤4

Source: Nippon steel technical report (200)

Figure 10 Air Pollution Control System in small foundry factory

1.9 Related Regulations, Air quality standards

Table 7 Industrial Emission Standards

No.	Substance	Source	Standard value	
			Non combustion Unit	Combustion Unit
1.	Particulate matter	Boiler		
		-Heavy oil as fuel	-	240 mg/Nm^3
		-Coal as fuel	-	320 mg/Nm^3
		-Biomass as fuel	-	320 mg/Nm^3
		-Other fuel	-	320 mg/Nm^3
		Aluminum	300 mg/Nm^3	240 mg/Nm^3
		manufacturing	400 mg/Nm^3	320 mg/Nm^3
		Other sources		
2.	Antimony	Any source	20 mg/Nm^3	16 mg/Nm^3
3.	Arsenic	Any source	20 mg/Nm^3	16 mg/Nm^3
4.	Copper	Any source	30 mg/Nm^3	24 mg/Nm^3
5.	Lead	Any source	30 mg/Nm^3	24 mg/Nm^3
6.	Mercury	Any source	3 mg/Nm^3	2.4 mg/Nm^3
7.	Chlorine	Any source	30 mg/Nm^3	2.4 mg/Nm^3
8.	Hydrogen Chloride	Any source	200 mg/Nm^3	160 mg/Nm^3
9.	Sulfuric acid	Any source	25 ppm	-
10.	Hydrogen sulfide	Any source	100 ppm	80 ppm
11.	Carbon monoxide	Any source	870 ppm	690 ppm

Table 7 (Continued)

No.	Substance	Source	Standard value	
			Non combustionUnit	Combustion Unit
12.	Sulfur	Boiler		
	Dioxide	-Heavy oil as fuel	-	950 ppm
		-Coal as fuel	-	700 ppm
		-Biomass as fuel	-	60 ppm
		-Other fuel	-	60 ppm
		Other sources	500 ppm	-
13.	Oxides of	Boiler		
	nitrogen	-Coal as fuel	-	400 ppm
		-Biomass as fuel	-	200 ppm
		-Other fuel	-	200 ppm
14.	Xylene	Any source	200 ppm	-

Remark; 1. Fuel combustion means the process in which fuelcomposition react with oxygen generating heat energy, such as the fuel combustion in boiler, the combustion cement, kiln,the metal foundries manufacturing and solid waste incineration.

2. Biomass fuel means the fuel produced from organic substances or Organism including products from the agriculture, farming and forestry, for example,firewood, wood chip, husk, straw,trunk and leaves of sugar cane, fiber of palm,bunch of palm, fiber of coconut tree, feces,biogas, sludge or waste from the agricultural product industries.

3. The monitoring results of air emission from non-combustion source are reported as concentrations at the reference condition of 1 atm or (760 mmHg),25 C, dry basis and actual % oxygen.

4. The monitoring results of air emissions from fuel combustion source are reported as concentrations at the reference conditions of 1 atm or (760 mmHg),25 C, dry basis and 50 % excess air (or 7% oxygen)

Source: Secot CO.LTD, (2006)

Table 8 Permissible Heat Exposure Threshold Limit Values (Value are given in C.WBGT)

Work-Rest Rest Regimen	Worked Load			
	Light	Moderate	Heavy	Very Heavy
Continuous work	29.5	27.5	26.0	-
75% Work –25% Rest, Each hour	30.5	28.5	27.5	-
50% Work –50% Rest, Each hour	31.5	29.5	28.5	27.5
25% Work –50% Rest, Each hour	32.5	31.0	30.0	29.5

Remark: Wet Bulb Globe Temperature Index

Source: ACGIH American (Conference of the Governmental Industrial Hygienists), (2000)

Table 9 Heat Occupational Health and Safety Measures in working Environment for Factory Enterprise

Work Load	Heat Level Standard Average WBGT C
Light work load	34.0
Moderate work load	32.0
Heavy work load	30.0

Source : Notification of the ministry of Industry regarding Working Environment Environment Occupational Health and safety Measurements issue under Factory Act.B.E.2535 (1992), published in the Royal Government Gazette, Volume 120,Part 138D ,dated December 3,B.E.2546 (2003).

Table 10 Noise**:** Occupational Health and Safety Measures in working Environmental for Factory Enterprise.

Working Hours for Noise Exposure per Day (hr)	Average sound pressure level not exceeding (hr)
12	87
8	90
6	92
4	95
3	97
2	100
1.5	102
1	105
0.5	110
0.25 or less	115

Remark : In the working area where the sound pressure levels exceed the standard, Warning notification is to be posed. No entrance in the working area where the sound pressure level exceed 140 dB (A)

Source: Notification of the Ministry of Industry regarding Working Environment, Occupational Health and Safety Measurements issued under Factory Act. B.E.2535(1992) ,published in the Royal Government,Gazette,Vol.120,Part 138D,date December 3,B.E.2546 (2003)

2. Review on Air Pollution Control

2.1 Definition of Air Pollution

Air pollution is introduction of substance into the atmosphere that is not normally present there in (Chemical Composition of the Atmosphere which are shown in Table 11 and 12) such as dust, mist, smoke,gas, vapor, fume and has harmful effect on human, animals or plant life. From this definition,the key factors of air pollution are outdoor atmosphere, air contaminant, quantity and characteristics, duration and adverse effects of air pollutant.

Table 11 Main Constituents of the Atmosphere

Constituent	Chemical Formula	Concentration(%V)
Nitrogen	N_2	78.0084
Oxygen	O_2	20.946
Argon	Ar	0.934
Other inert gases	Ne,He,Kr,Xe	Less than 0.002
Hydrogen	H_2	0.50 ppmV

Source: Hooper,Design of Air Pollution Control System (2007)

Table 12 Variable Concentration-across Human Experience

Constituent	Chemical Formula	Concentration(ppm V)
Carbon dioxide	CO_2	350 ppm V
Water vapors	H_2O	0-3 (%V)
Methane	CH_4	1.67 ppm V
Nitrous oxide	N_2O	0.30 ppm V
Carbon monoxide	CO	0.19 ppm V
Ozone(ground level)	O_3	-0.02-0.04 ppm V

Table 12 (Continued)

Constituent	Chemical Formula	Concentration(ppm V)
Ammonia	NH_3	0.004 ppm V
Nitrogen dioxide	NO_2	0.001 ppm V
Sulfur dioxide	SO_2	0.001 ppm V
Nitric oxide	NO	0.005 ppm V

Source: Hooper (2007)

2.2 Air Pollutant Source Classification

Air pollutant source can be classified into two abroad categories, i.e., natural source and anthropology source. Examples of natural source are wind-blown dust, volcanic ash and gases, etc. These pollutants cause fewer problems than human-made air pollutants. The anthropology source is a major cause of air pollution because in each year human-beings' activities produce air pollutants in high quantities. Factories are important sources which cause air pollution problems and effect to health. Long-term exposure to air pollutants can cause cancer, damage to the immune, neurological, reproductive, and respiratory system. In extreme case, air pollution can cause death.

The Promotion and Development Energy Department reported in 2,000 that an industrial and energy group activities released pollutants in the highest quantity. Details are shown in Table 13. Patcharawadee Suwantada (2007) pointed out that 80 % of PM_{10} in ambient air came from industrial sources like fuel burning, boiler, garment industries,etc.

The severe areas which have this problem in Thailand are Samutprakarn and Saraburee provinces. In Bangkok, TSP and PM10 from roadside are the main sources.

Table 13 Air Emission Classified by activity 2543 (Unit 1000 Ton)

Pollutants	Industrial Process	Transportation	Energy	Domestic and commercial	Others	Total
TSP	6	16	153	0	10	185
CO	136	453	31	2,051	88	2,759
NOx	137	208	161	28	106	640
SO_2	220	21	341	1	4	587
CO_2	30,922	46,401	57,788	4,306	7,143	146,560
CH_4	3	4	4	43	1	55

Source: The Promotion and Development Energy Department (2000)

2.3 Air Pollution Problem from Foundry Factories

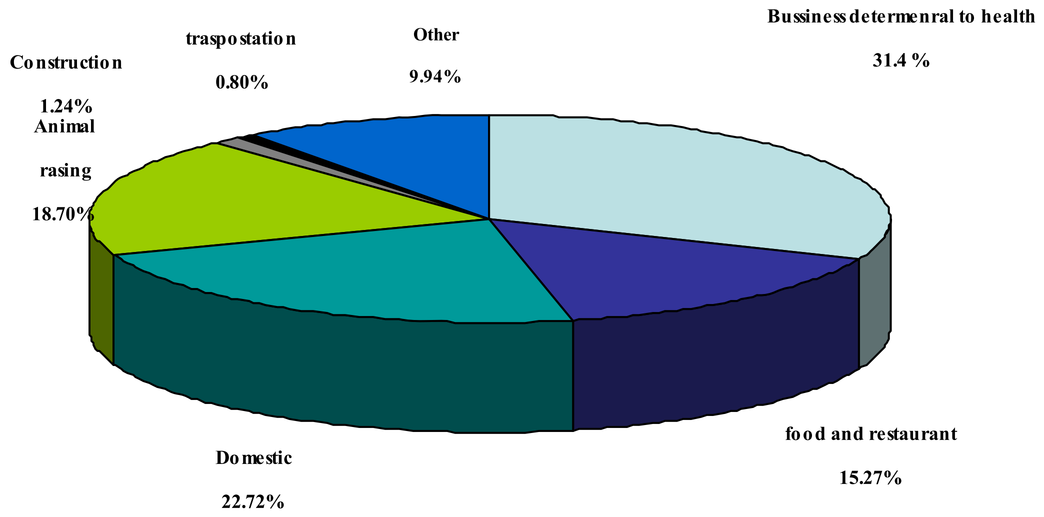
Each process of these factories produces waste and is harmful to workers in workplace and other people who live near the factory.Jongcharoensrisiri (2007) pointed out that one foundry factory located in Ayuthaya province, with a notice from the Department of Industrial Works, had improved the process following the authority‘s comment, but there were still some complaints from nearby residents about odor and smoke. This factory uses cupola in the process. The monitoring data showed that the emission from stack had high CO concentration (5,783 ppm), which was over the government standard (690 ppm). Besides air pollution, many factories also cause other nuisance problems such as noise,Table 14

Table 14 Statistic of Nuisance Problems in 1999- 2001

Problem Types	1999		2000		2001	
	number	%	number	%	number	%
Noise and air pollution	2,238	58	4,333	77	2,559	72
Water pollution	806	21	787	14	578	16
Hazardous waste	105	4	333	6	150	4
Others	651	17	187	3	284	8
Total	3,845	-	5,637	-	3,571	-

Source: Pollution Control Department (1999- 2001)

In Bangkok the number of environmental nuisance source which were brought in 2006 reported by the Environmental Sanitation Division, Health Department, BMA, were 7343 sources. Among these, 31.34% came from the industrial source, as shown in Figure 5.Air pollution problem like particulate and smoke 8 %, unpleased odor from industrial process, 34.55%,.The trend of these problems has been increasing every year.



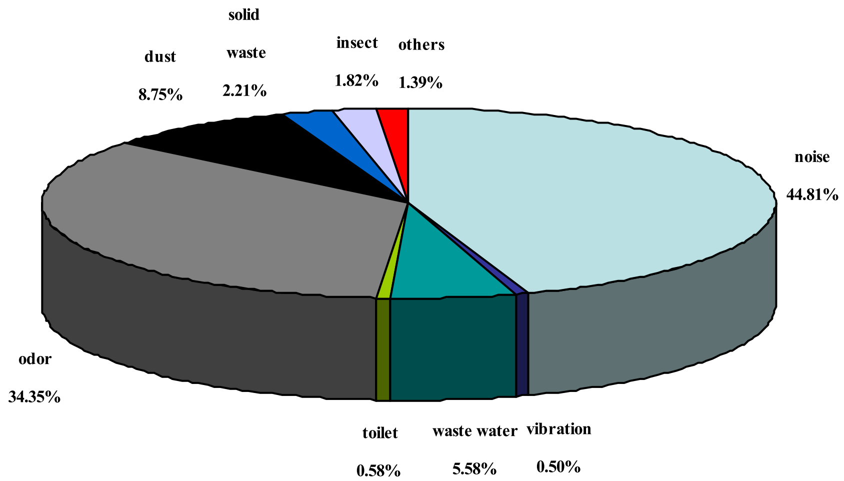


Figure 11 Source of nuisance in Bangkok area,7374 Case,2006

Source: Environmental Sanitation Division (2006)

2.4 Air Pollution Control System

Particle Technology Control equipment for particulates falls into five General class(1) gravity settlers,(2) Centrifugal separator (Cyclones) ,(3) Electrostatic precipitators, (4) fabric filters, and(5) Wet scrubbers.Such equipment must be matched to the emission in term of variables such as flow rate, temperature, nature and concentration of pollutant, and designed degree of control. It is well recognized that no universal gas cleaning method exists which will satisfy all problem and conditions. The choice of method depends on both technical and economic factors.

2.4.1 Gravity settlers

This category of control devices relies upon gravity setting to Remove particles from gas stream. Gravity setting chambers are use only for every large particle in the upper end of the super coarse size range. The very low terminal settling velocities of the most particles encountered in the field of air pollution limit the usefulness of gravity setting chambers

Gravity settlers are usually constructed in form of a long, horizontal paralleled pipe with suitable inlet and outlet ports. In its dimpliest form the settler is Enlarged (large box) in the dust carrying the particle –laden gases; the contaminated gas stream enters at one end, the cleaned gas exits from the other end. The particles settle toward the collection surface at the bottom of the unit with a velocity at or near their terminal settling velocity. There are basically two types of gravity settler: the simple expansion chamber and the multiple–tray settling chamber.

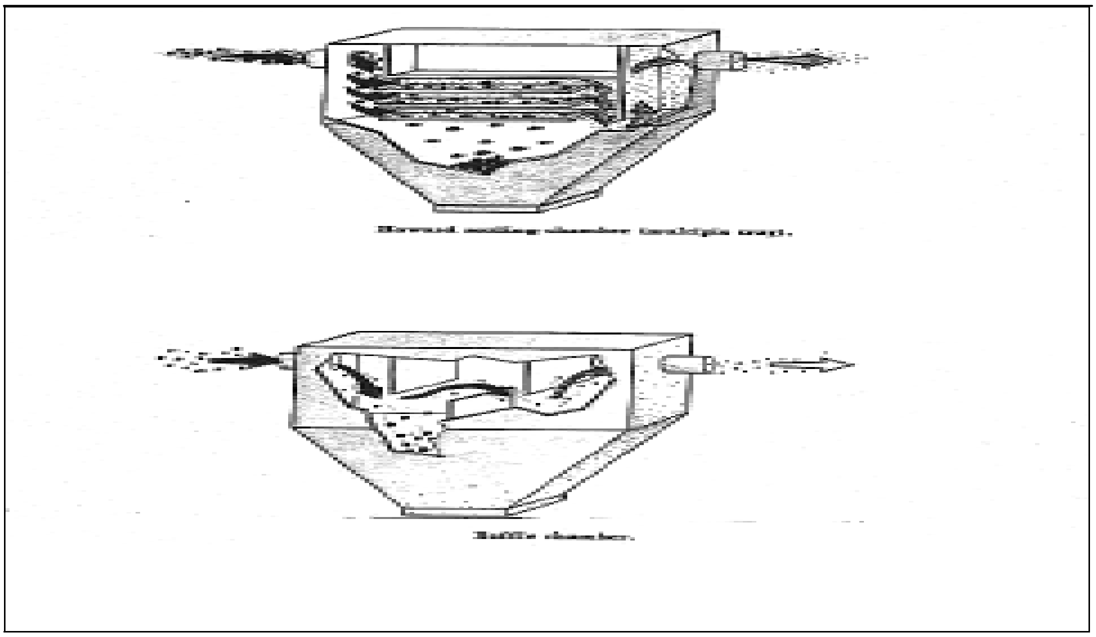


Figure 12 Gravity settlers
Source: Waravute (2005)

2.4.2 Centrifugal Separators

Centrifugal Separators, commonly referred to as cyclones,are Widely used in industry for the removal of solid and liquid (aerosol) from gas stream. Typical applications are found in mining and metallurgical operations, the cement and plastics industries, pulp and paper mill operations, chemical and pharmaceutical process, petroleum production (cat–cracking cyclones),and combustion operation (Fly ash collection),cyclones are mechanical collector used the inertia of the particles for collection. The particulate-laden gas stream forced to spin in may generally be classified in four categories, depended on how the gas stream enters the unit and how the collected particles leave the unit. (1) Tangential inlet and axial dust discharge (2)Tangential inlet and peripheral dust discharge. (3) Axial inlet and axial dust discharge (4) axial inlet and peripheral dust discharge

There are many different types of dust collection equipment using centrifugal separation to collect particles entranced in gas streams. Conventional cyclone can be designed to handle a wider range of chemical and physical conditions of operation than most other types of dust collection equipment. Any conditions for which structural materials are available can be met by a cyclone, provided that the degree of collection falls within the operating range of the cyclone and the physical characteristic of the particulates are such that know fouling of the cyclone or excessive wall buildup will occur. Because of its versatility and low cost, and the fact that there are no moving parts, the single cyclone separator is probably the most widely use of the dry centrifugal separator. Although many design factors-musts be considered, the degree of collection efficiency is most dependent on the horsepower expended. Therefore, cyclones with high inlet velocities, small diameters, and long cylinders are generally found to be the most efficient. However, there are limit to all of these parameter .Conventional cyclones of medium efficiency (80 to 95 %) are capable of handling high throughout at pressure losses typically between 2.0 to 5.0 in of water. Body diameters are fairly large (4 to 12 ft or larger).High efficiency (95 to 99 %), single cyclone unit are generally long and narrow and seldom have a body diameter larger than 3 ft diameter. Pressure drop typically range from 2 to 6 inch of water.

Multiple-cyclone collector is another high-efficiency system, consist of a number of small diameter cyclones operating in parallel with a common gas inlet and outlet, flow pattern differs from a conventional cyclone in that instead of bringing the gas in at the side to initiate the swirling action is then imparted by a stationary vane positioned. In the path of the coming gas, the diameters of collecting tubes usually range from 6 to 24 in. with pressure drop in the 2-6 in. range Properly designed units can be constructed and operated with a collection efficiency as high as 90% for particle in the 5-to 10 – um range. The most serious problems encountered with this system involve plugging and flow equalization.

Another type of available collector is that in which centrifugal force is supplied by a rotating. The unit serves both as an exhaust fan and a dust collector. In operation the rotating fan blades exerts a large centrifugal force on the particles, ejecting them from the tip of the blades to a skimmer bypass leading into a dust hopper. Efficiency of this system is somewhat higher than those obtained with conventional cyclones. Mechanical centrifugal collector is compaction; however, they can not generally be used to collector inlet. Impeller blades are also susceptible to erosion.

There are many other systems capitalizing on centrifugal forces. Many of these systems utilize water to assist in the collection mechanism, in cyclonic spray chambers the dust laden gas enters tangentially at the bottom and spiral up through a spray of high-velocity fine water droplets. The dust particles are collected on the fine spray droplets which are then hurled against the chamber wall by centrifugal action. Other units utilize water to wet and entrap the particle separated from the gas stream by centrifugal action.

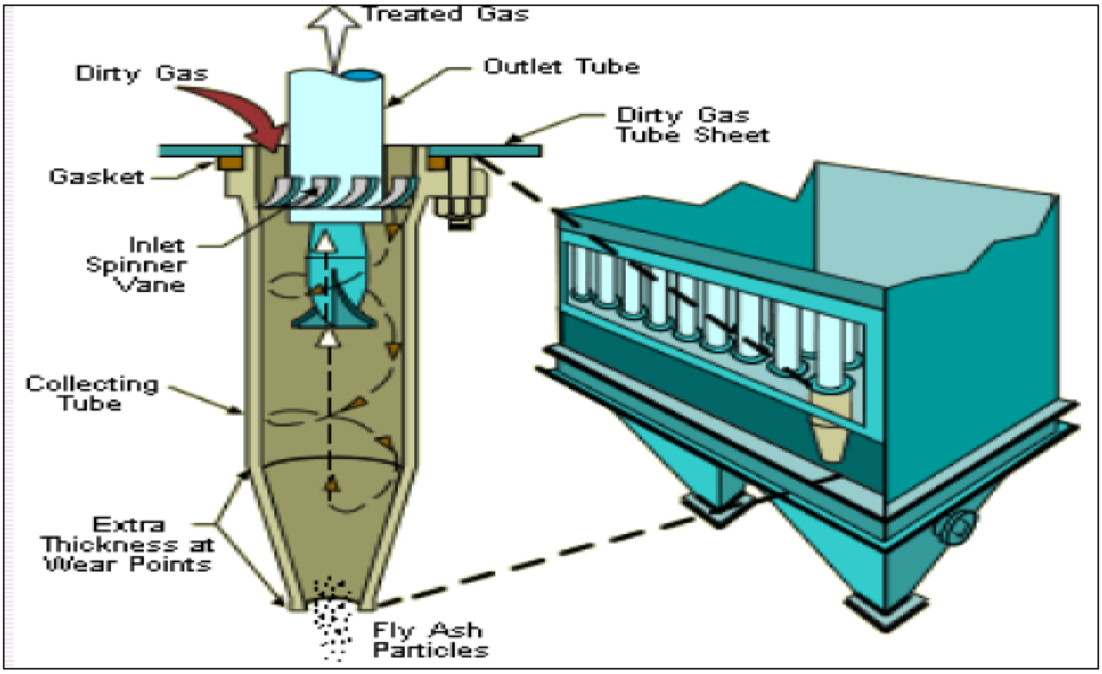


Figure 13 Arrangement of cyclone

Source: Waravute (2005)

2.4.3 Electrostatic Precipitators

Electrostatic precipitator technology was developed in the U.S. by Dr. Frederick Gardner Cottrell at the turn of the century. Cottrell ‘ s precipitator was successfully applied in 1907 to the collection of sulfuric acid mist and shortly thereafter proven in a number of ore processing, chemical, and cement plants.

The electrostatic precipitator may be classified as either a high voltage, single stage or low-voltage, two-stage system. The high voltage type is by far the more popular; it has been used successfully to collect both solid and liquid particulate matter from many operation including smelter, steel furnaces, petroleum refineries, and utility boilers. Low-voltage, two-stage precipitators, on other hand , are limited almost exclusively to the collection of liquid particles discharged from sources such as meat smokehouses, asphalt paper saturators, pipe -coating machine ,and high speed grinding Machine also.

Electrostatic precipitator design, essentially the entire unit is divided into a numbers of separately energized areas that are term fields, most precipitators have between three and ten field in series along the gas flow path. On large unit, the precipitators are divided into a number of separate, parallel chambers, each of which has an equal number of fields in series; there is a solid partition or physical separation between the 2 to 8 chambers that are present on the large system

Collection Efficiency of Electrostatic precipitator is usually at a minimum in the range of 0.1 to 0.5 micrometers. The shape of the efficiency curve is the combined effect of two particle electrical charging mechanisms, neither of which is highly effective in this particle size range. It should be noted that decrease in efficiency occurs in the same particle size range as for particulate wet scrubbers; however the reason for this decreased efficiency zone is entirely different than that for particulate wet scrubbers

2.4.4 Particulate Wet Scrubbers

There are a number of major categories of particulate wet scrubbers.The list is not exhaustive ,ventures, Impingement and Sieve plates, Spray Towers,others are Mechanically Aided ,Condensation Growth,Packe Beds,Ejector, mobile Bed,Caternary Grid, Froth Tower ,Oriented Fiber Pad, Wetted Mist Eliminator, Venturi Scrubbers a typical venture throat, particle matter, which accelerates as it enters the throat, is driven into the slow moving, large water droplets that are introduced near the high velocity point at the inlet gas stream

2.4.5 Impingement Plate Scrubbers

An impingement usually has one to three horizontal plates, each of which has a large number of small holes. the gas stream accelerating through the hole atomizes some water drop in the water layer above the plate. Particles impact into these water droplets.

Collection Efficiency of wet Scrubbers, all of the particulate wet scrubbers in commercial use depend on impaction. However the velocities of the particle –laden gas stream and the liquid targets vary substantially. Accordingly, there are substantial differences in the ability of particulate wet scrubbers to collect particles less than approximately 5 micrometers. If a portion of the particulate matter mass is composed of particles less than 5 micrometers, care is needed to select the type of scrubber that is effective in this size range.

Limitations of we scrubbers, It should be noted that some types of wet scrubber have limited capability to remove particles in the less than 0.3micrometer range .Method of particle collection in this vary small size range take advantage of these particles' tendencies to diffuse slowly due to their interactions with gas molecules (Brownian diffusion) .In other word, these particles are so small that their movement is influenced by collisions with individual molecules in the gas stream.

Advantages of scrubbers, many types of particulate wet scrubbers can provide high efficiency control of particulate matter. One of the main advantages of particulate wet scrubbers is that they are often able to simultaneously collect particulate matter and gaseous pollutants. Also, wet scrubbers can often be used on sources that have potentially explosive gases or particulate matter. They are compact and can often be retrofitted into existing plants with very limited space.

Disadvantages of scrubbers, one of the main disadvantages of particulate wet scrubbers is that they require make-up water to replace the water vaporized into the gas stream and lost to purge liquid and sludge removed from the scrubbers system.Wet scrubbers generate a waste stream that must be treated property.

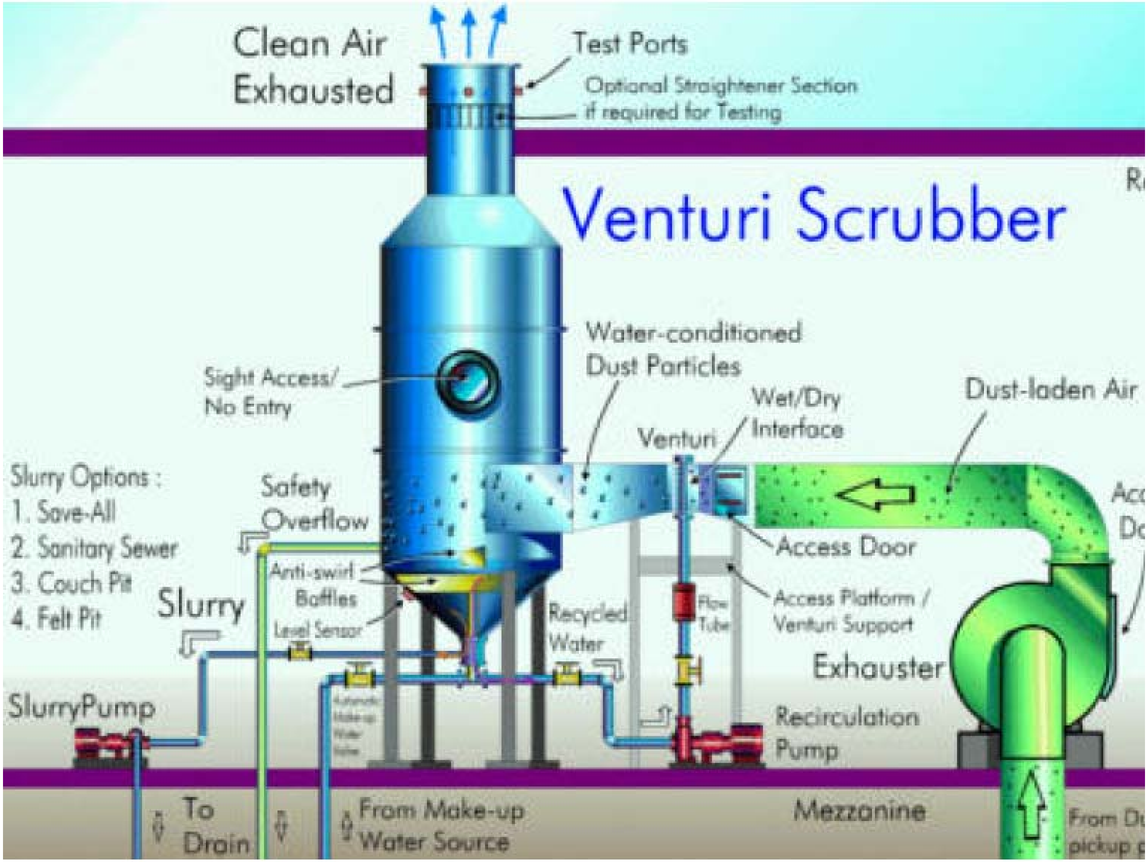


Figure 14 Structure of venturi scrubber

Source: Waravute (2005)

MATERIALS AND METHOD

As previous mention, the study background were people's complaint About air polluted emission of foundry factories in Phetkasem 51 Road,Bangkhare District, Bangkok in 2546 B.E. which were 11 foundry factories located in there. Even though government agency had enforced factories 's owner to do redesign their facilities and process for better air pollution control but people were always complaining. In 2549 B.E. there were 7 factories, and later in 2551 B.E. the number of foundry factories was decrease to 5. Therefore this study only present for 5 foundry factories and the study purpose is to find out resolving air pollution problem by applying engineering principle integrated with social strategy.

Materials

1. The TESTO 350 Model Emission Analyzer was used in Stack Emission Testing,for CO, NO_2, SO_2 measurement. The model design provides vast opportunities to configure an analyzer system for specific testing requirement. The most accurate sensors for low range NOx and CO (0.1ppm) or swap out for higher range testing.
It integrated dilution system for extended testing ranges, grater sensor protection and unlimited testing possibilities the detail is shown in table 15

Table 15 TESTO 350 Model Emission Analyzer's specification

Pollutants	Range	Accuracy	Resolution
O_2	0 to 25% vol.	< 0.2% of m.v.	0.1 vol. %
CO	0 to 10,000	< 5 ppm (0 to 99 ppm)	1 ppm
	Ppm H_2 comp.	< 5% of m.v. (100 to 2,000 ppm)	
		<10%of m.v.(2,001to10,000 ppm)	
CO low	0 to 500 ppm	<2 ppm (0 to 39.9 ppm)	0.1 ppm
	H_2 comp.	< 5% of m.v. (40 to 500 ppm)	

Tale 15 (Continued)

Pollutants	Range	Accuracy	Resolution
NO	0 to 3,000 ppm	<2ppm (0 to 39.9 ppm) < 5% of m.v. (300 ppm)	0.1 ppm
NO_2	0 to 500 ppm	< 5 ppm (0 to 99 ppm) < 5% of m.v. (500 ppm)	0.1 ppm
SO_2	0 to 5,000 ppm	< 5 ppm (0 to 99 ppm) < 5% of m.v. (100 to 2,000 ppm) < 10%of m.v.(2,001 to 5,000 ppm)	1 ppm
S_2	0 to 300 ppm	< 2 ppm (0 to 39.9 ppm) < 5% of m.v. (40 to 300 ppm)	1 ppm
C_xH_y	0.01 to 4%	< 400 ppm (100 to 4,000 ppm) < 10% of m.v. (> 4,000 ppm)	0.01 vol. %= 10ppm
CO_2	0 to 50% vol.	± 0.3%vol.+1of m.v (0to25%vol.) ± 0.5% vol. +1.5% of m.v (>25 to 50% vol.)	0.01% vol. (0 to 25%vol.) 0.01% vol. (> 25% vol.)
CO_2 (Calculated)	0 to CO_2 max vol. %	Calculated from O_2	0.1 vol. %
Differ. Press. 1	± 80" H_2O	< 1% m.v. (-20" to 80" H_2O) < 1% m.v. (+20" to +80" H_2O) < 0.5% m.v. (-19" to +19" H_2O)	0.01" H_2O
Differ. Press. 2	± 16" H_2O	< 1% m.v. (16" to 1.2" H_2O) < 1% m.v. (+16" to +1.2" H_2O) < 0.5% m.v. (-1.2" to +1.2" H_2O)	0.01" H_2O
Efficiency	0 to 100%		0.1%
Current Voltage	0 to 20 mA	± 0.04 mA	± 0.01 mA
Flow Velocity	0 to 7900 ft/min		10 ft/min
Temp	-40 to 2192°F	± 0.9° F (-40 to +212° F) ± 0.5% m.v. (+212 to +2,192° F)	
Methane	0.001 to 4%[2]	See C_xH_y	See C_xH_y
Propane	0.01 to 2.1%[2]	See C_xH_y	See C_xH_y

2. The scientific instruments for Ambient Air Quality Measurement in community area

2.1 Wind direction and wind speed by using the wind speed and wind Direction Kit, 24 hours a day, from BMA Air Mobile Service.

2.2 Total Suspended Particulate measurement by using TSP High Volume Samplers feature accurate collection of total suspended particulates exceeding EPA specifications. Air flow through the system is maintained at a constant rate by an electronic probe with automatically adjust the speed of sampler to correct for variations in line voltage temperature, pressure and filter loading. Adjustable over arrange from 20 SCFM to 60 SCFM the air flown is controlled at constant standard condition of 25˚C temperature and 760 mmHg pressure within plus or minus 1 SCFM by maintenance an exact air flow rate through the sampler, the average concentration measured is extremely accurate and reliable. Control Accuracy +/- 2.5 % deviation over 24 hour sampling period.

2.3 PM-10 measurement by using GMW PM-10 High Volume Sampler which used volumetric Flow Controlled (VFC) with a dimensional venture device for gas flow control. When apply to a high volume air sampler, this gas flow control principal incorporates a smooth-wall venture orifice that gradually open to a recovery section. Vacuum is provided by a motor downstream of the venture. Over 95% of the energy lost in differential pressures across the restricting orifice is recovered in this design.

2.4 Ambient Air Quality Measurement by using Miran Sapphire-XL Portable Ambient Air Analyzer. It is the product of hundreds of customer and industry inputs on ideal multi-gas analyzer design. It used for industrial hygiene monitoring. Emergency Response Analysis, Indoor Air Quality Studies, Hospital Gas Monitoring, Fume Hood, Tracer Gas Testing and Leak Detection. Using of infrared spectroscopy provides the MIRAN SapphIRe Analyzers with the unique ability to specifically and accurately measure many gases with a single unit. The analyzer's wavelength generator has unique design that allows accurate and fast wavelength selection.

2.5 The Universal Sample pump is a constant flow air sampler with high and low flow setting application. It is specifically designed for “on worker” and “fen line” application ,typically use with collecting devices such as filters , impinger, sorbent sample tube and sample bag was used in Air Sampling for measurement of Volatile Organic Compounds on community. Its Specifications are

1) Operating Range: 5-5000 ml/mil, Compensation: 750 to 2500 ml/min-to 40 inches water back pressure
2) Range: 2500 to 4000 ml/min-to 20 in water back pressure, Flow Control: ±5% set point constant flow
3) Running Time: 8 hrs min at 4000 ml/min & 20 in water back pressure Flow Indicator: Built-in flow indicator with 250 ml division; scale marked at 1, 2, 3, 4, & 5 LPM
4) Battery Plug in battery pack, rechargeable NiCad 2.0 Ah,Assembly: 6.0 V UL Listed.
5) Intrinsically UL Listed for: Class I, Groups A, B, C, D;
6) Safe: Class II, Groups E, F, G; and Class III. Temp Code T3C.

Multiple Built-in constant pressure regulators allows user to take Sampling: up to four simultaneous samples at different flow rates up to500 ml/min (maximum total combined flow1350 ml/min) using optional low flow control.

2.6 Gas chromatography - specifically gas-liquid chromatography involves a sample being vaporized and injected onto the head of the chromatographic column. The sample is transported through the column by the flow of inert, gaseous mobile phase. The column itself contains a liquid stationary phase which is adsorbed onto the surface of an inert solid. The schematic diagram of a gas chromatograph is

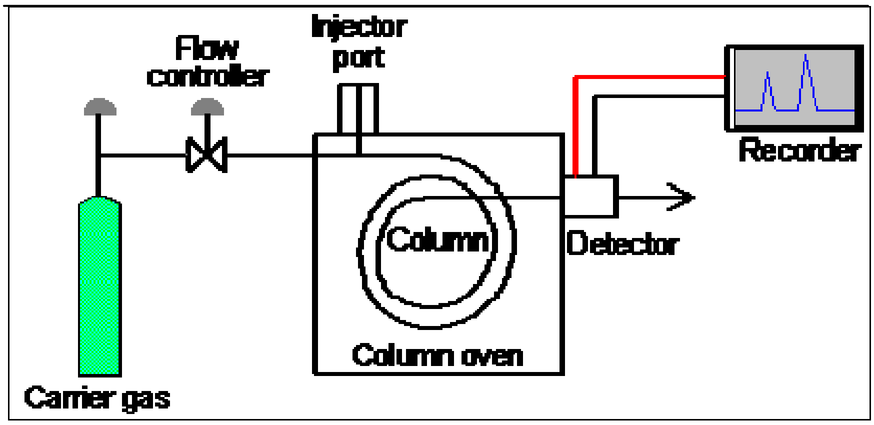


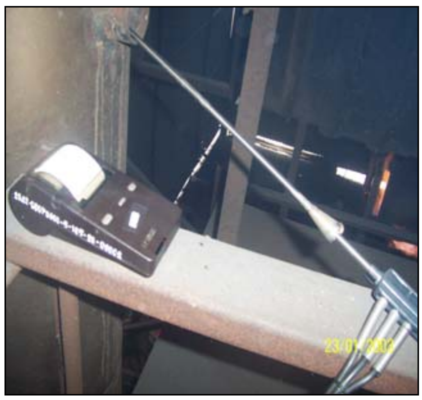
Figure 15 Diagram of a gas chromatograph

Sorce: SKC.CO.LTD,(2008)

TSP High Volume Sampler

GMW PM 10 High Volume Samplers

Miran Sapphire



The TESTO 350 Model Emission Analyzer

Figure 16 Scientific Instrument 1

Source: Department of Health,BMA (2008)

Gas chromatography

Mobile Air Monitoring Unit

The Universal Sample pump

Wind direct and wind direct speed Kit

Figure 17 Scientific Instrument 2

Source: Health Department, BMA (2008)

Methods

1) Review all existing relevant complain since 2546-2551 from complaint and related agencies i.e.Bangkhae Distric Office, Health Department BMA,PCD,DIW

2) Surveyed the foundry factories area and collected relate information included location, raw materials, production process, and engine power etc.in 2549, 2550 and 2551 B.E.consequently.

3) Review the background information about current stage of air pollution Control systems including physical identity and effectiveness.

4) Review the capacity of hood in the foundry factory relevant to the collecting smoke to air pollution system in foundry factories.

5) Review the efficiency of the air pollution control system. Stack emission Testing, both inlet and outlet in 2546,2548,2549,2550and 2551 B.E. by using gas analyzer which has been approved by regulatory agency. Parameters were measured are CO, NOx, SO_2, and TSP since each of 5 foundry factories has different work period and the temperature near the stack were very high so the testing was established only one foundry factory in one day.The stack emission testing start from after cupola's working more than 45 minutes and then preparing Testo 350 Model Emission Analyzer, measure, record data ,procedure's detail shown this following

- Prepare Testo 350 Model Emission Analyzer
- Mark sampling point on the stack, in this study every foundry factories have one hole already.
- While measurement, put Testo probe in to a hole about 3-5 minutes in each time or until the pollutants 's value which show in LCD monitor will steady. If the pollutants 's value show in negative results it means instrument error due to temperature in stack is too high, a measurement should stop and take a Testo's probe in fresh air until it cool down. In this study the researcher have taken a measure 5 values for each foundry factory ,total time 30 minutes.
- Record the data 5 values for CO,NOx,SO_2 then calculate average values for each foundry factory .The testing show in figure 18

Figure 18 Stack Emission Testing

6) Comparing the measurement outcome data (average value) with the Industrial Source Emission Standard notification of the ministry of Industry is issue under Factory Act 2535 B.E.

7) Ambient Air Quality Measurement for some gases and particulates by approve quality assurance procedures and accurate scientific equipments. The parameter were wind direction and wind speed (used BMA Air Mobile Service) , Total Suspended Particulate (TSP) and PM-10 Cabon Monoxide (used high volume technique) ,Oxides of Nitrogen (NOx), Sulfur Dioxide (SO_2). The measurement emphasized on the factory working day ,3 point ,the 1st compliant's house area 455/20,the 2nd 457/20 and Bangkare Nuang Sang Wan school in 2549 B.E. The detail this following

7.1 Compliant's house (2 houses) which located in front of Phetkasem 51 Road, roadside Phetkasem Road and behind the foundry factory No.1,No.2 and No.3. The measurement was setup in dry season on 24th may to 30th may 2006 continuous 24 hours a day. The sampling point at both compliant's house took at room which near foundry factory to reduce traffic pollutants from roadside

- Set up and calibrate TSP High Volume Samplers and GMW PM-10 High Volume Samplers
- Prepare vinyl chloride filters by put in desiccators 24 hours and weigh and calculate the filter weight before sampling
- Set up a measurement at both compliant 's house in same time by separate staff and instrument to 2 groups and changed filter every morning until finish a measurement.
- TSP's weight and PM -10 =Weight before sampling (mg/m^3) – Weight after sampling (mg/m^3)
- NOx,CO,SO_2 measure by automatic analyzer on Air Monitoring Mobile Unit which is method approved by DIW. It is real time monitoring and measure continuous 24 hours

7.2 Bangkhae School is primary level education which located in the end of Phetkasem 51 Road.The measurement was set up on 1st June to 7th June 2006(7 days),it use the same procedure like compliant 's house showed in figure 19

Figure 19 Ambient Air Quality Measurements

8) Ambient Air Quality Measurement in the day without foundry factories working. Because in a week there were only 2 days that factories was not operate, Tuesday and Thursday, so the measuring was set up on Thursday the point were Bang Kare Nuang Sang Wan School, to measure stack emission gaseous by Toxic gas Analyzer , Miran Sapphire, for CO, SO_2, and NOx , the points were in front of the school and surround communities such as upper road and end of road. Figure 20 showed the point and measurement process.

Figure 20 Community area.
Source: Environmental Sanitation Division, BMA (2007)

9) Compare the data from measurement ambient air and toxic gas on community regulated standard the ambient Air Quality standard, Notification of the National Environmental Board, NO.10, 2538 B.E (1995) and also the Public Health Act. 2535 B.E.

10) Define the integrated resolution criteria for the factory owner, Bangkok and also population in the surrounding area. by repair recently their air pollution control system redesign Air Pollution Control System; packed column and integrated way to increase efficiency Pollution Control System on sustainable way.

Figure 21 Stack Emission Testing Point

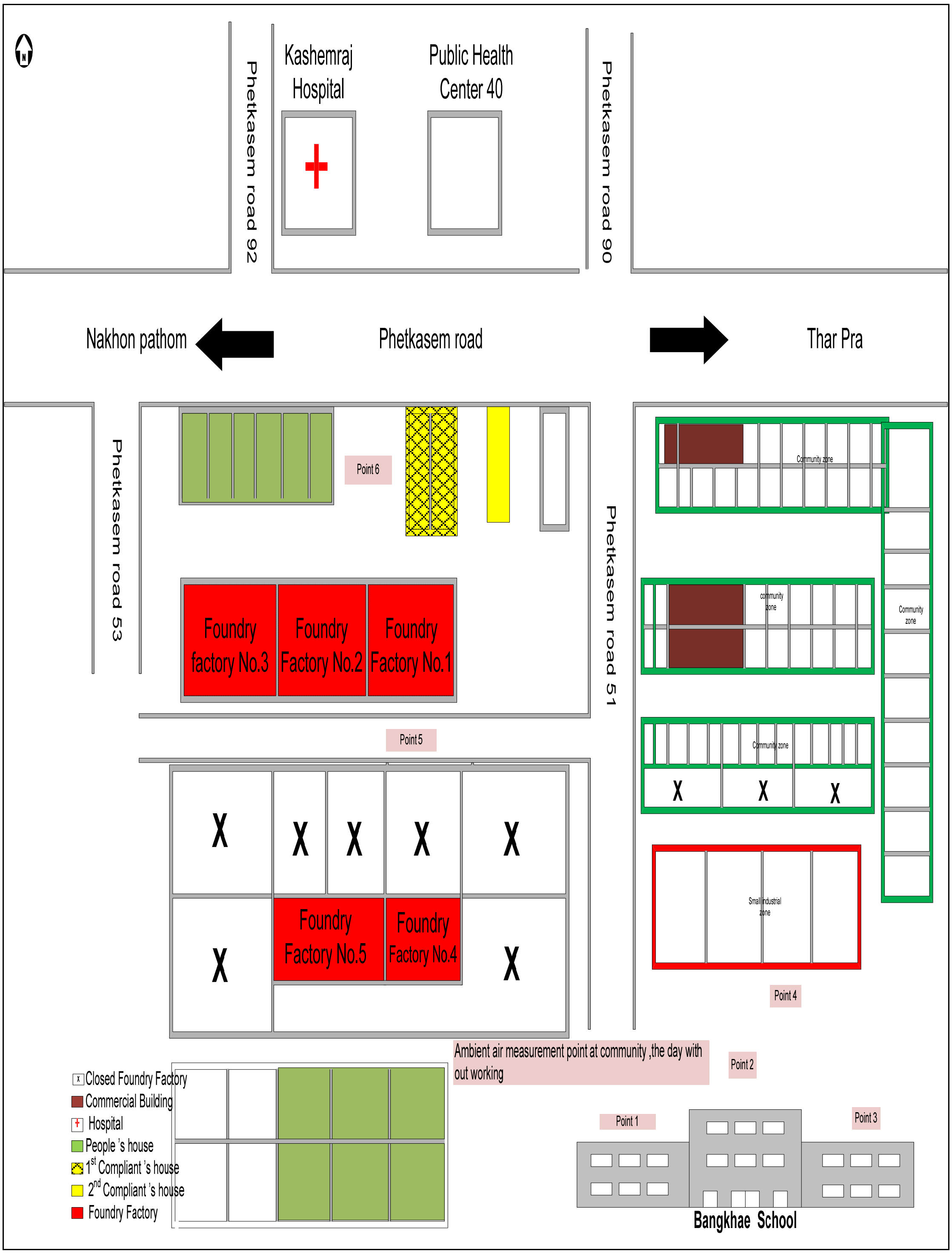


Figure 22 Ambient Air Measurement Point at community, the day without working

11) Air toxic measurement, Air sampling in charcoal tube to find out metal fume in workplace area (15 points for 5 foundry factory) was set up on August 2006 the details are this following

- Set up personal pump flow rate 3 set at less than 0.2 liter /minute and calibrate by Dry Cal Model and record the data
- Select sampling point which related with pollutant in each foundry factory
- Connect pump with charcoal tube and accessories, set up measurement duration 1 tube for 1 sample ,1 point ,60 minutes
- Calculate volume from flow rate and time , labels information on samples and sent to laboratory.

Table 16 Sampling point in workplace

Foundry Factories	Number of sampling point	Area	equipments
No.1	3	1.Worker who work in melting procedure ,in front of cupola 2.Poring melted iron in the mold procedure 3.Molding procedure	1.Personal pumps in low flow rate 2.Charcoa tubes 3.GC and standard gas
No.2	3	Same area with No.1	Same area with No.1
No.3	3	Same area with No.1	Same area with No.1
No.4	3	Same area with No.1	Same area with No.1
No.5	3	Same area with No.1	Same area with No.1

12) People's companion, the research have talked to people and interview people who live in surrounding area, 30 people on April 2008 by these questionnaires

- How long have you been living in Phetkasem 51 Road
- How many day do you stay at home in one week
- Have you ever know about air pollution from foundry factories in Phetkasem 51 Road
- Have you known about government agencies 's enforcement after people's complain
- Do you please with foundry factory's improvement after government agencies's enforcement
- Do you think ,in recently foundry factory emission remain people's nuisance.

RESULTS AND DISCUSSION

1. Background Information

1.1 Foundry Factories Data

The survey in 2549 B.E. found the T N. and KD company had relocated to other areas. Later, in April 2551 B.E., other 4 factories were closed. Therefore currently there are only 5 foundry factories still locate in Phetkasem 51 Road. Table 17,18 and figure 23 show the details of foundry factory data.

Table 17 Closed foundry factories,April 2551 B.E.

No.	Suppose Name	Factory ID Nunber	Furnace Type	Worker (person)
1.	B.Factory	3-64(9)-160/22	Induction	13
2.	Y. Factory	3-59-4/20	Cupola Furnace	7
3.	Ti. Factory	3-75-(2) -4/19	Crucible	6
4.	Le. Factory	3-66-(2) -12/20	Cupola Furnace	5

Source: Health Department, BMA (2008)

Table 18 Present foundry factories,April 2551 B.E.

Foundry Factory	Location	Factory ID number	Furnace Type	Worker (person)
No.1	239/8	3-59-1/16	Cupola Furnace	10
No.2	239/9	3-59-3/21	Induction, Small size crucible	7
No.3	239/14	3-59-4/17	Cupola Furnace, Crucible	10
No.4	239/16	3-60-6 /17	Cupola Furnace	24
No.5	239/11	3-60-2 /40	Crucible	5

Figure 23 Foundry factories at present in Phetkasem 51 Road, Bangkhae

1.2 Surrounding area data

The study survey found the factories locate as a group in the same area and surrounded closely by around 50 houses. Moreover, there is Bangkhae School locates at the end of The Petchakasem Soi 51 Road, about 20 meters from the factory NO-4. The house that had complaints about the factory operation locate at number 455/20, behind the Factory NO-1, NO-2 and NO-3 about 15 meters. Between the house and factories have not buffer zone clearly, but only small tree. The nearby landmark is the main Phetkasem Road and Kasemraj Hospital. Summariry, the nearby landmark surround the factory are as below

North: The house of complain 455/20 and 457/20

South: Bangkhae School (N 14 ˚ 01.48́, E 101˚ 18.50 5́)

East: Petchakesem 51 Road and business office

West: Empty area and houses

Figure 24 Foundry factory location and surrounding area**.**

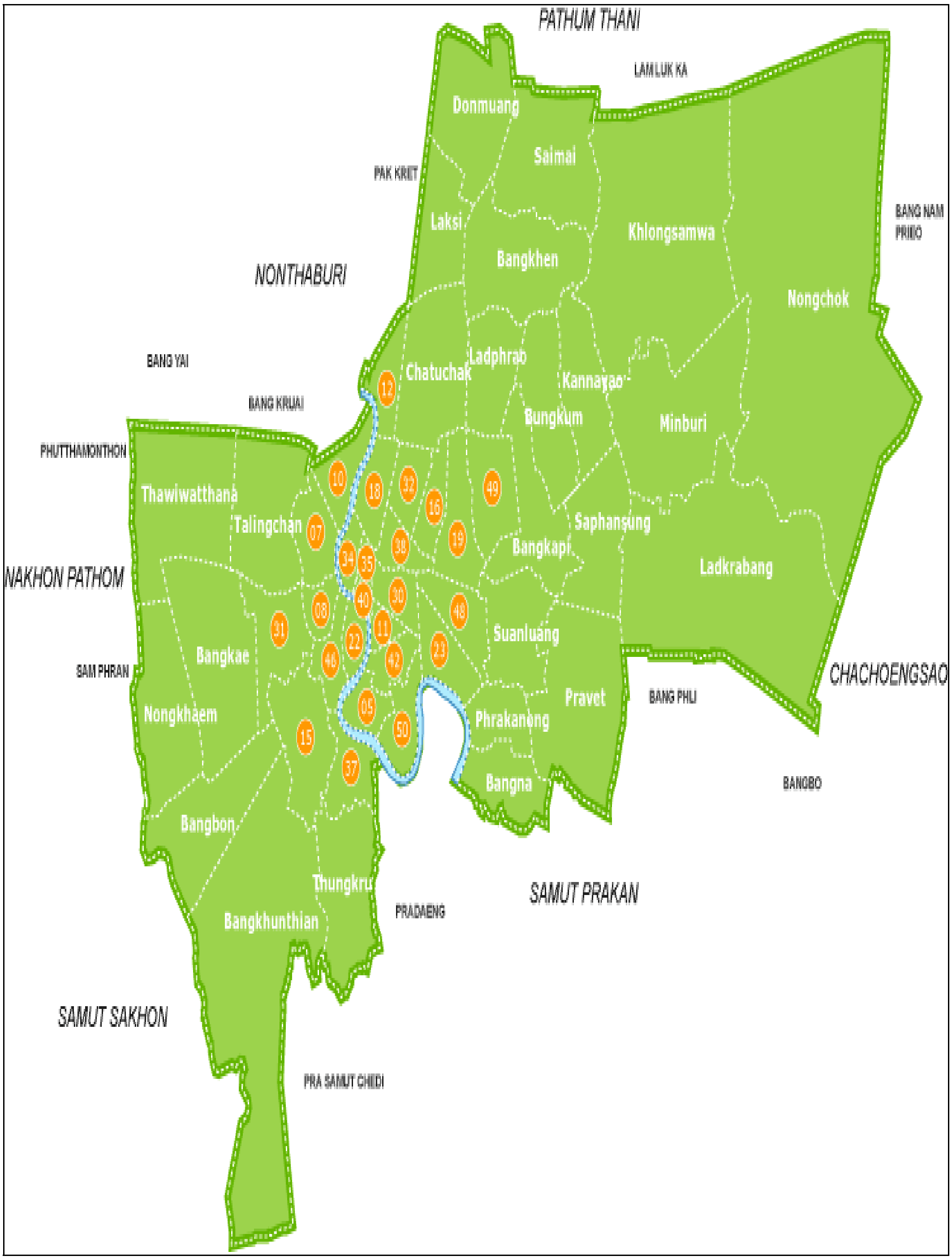


Figure 25 Bangkok map

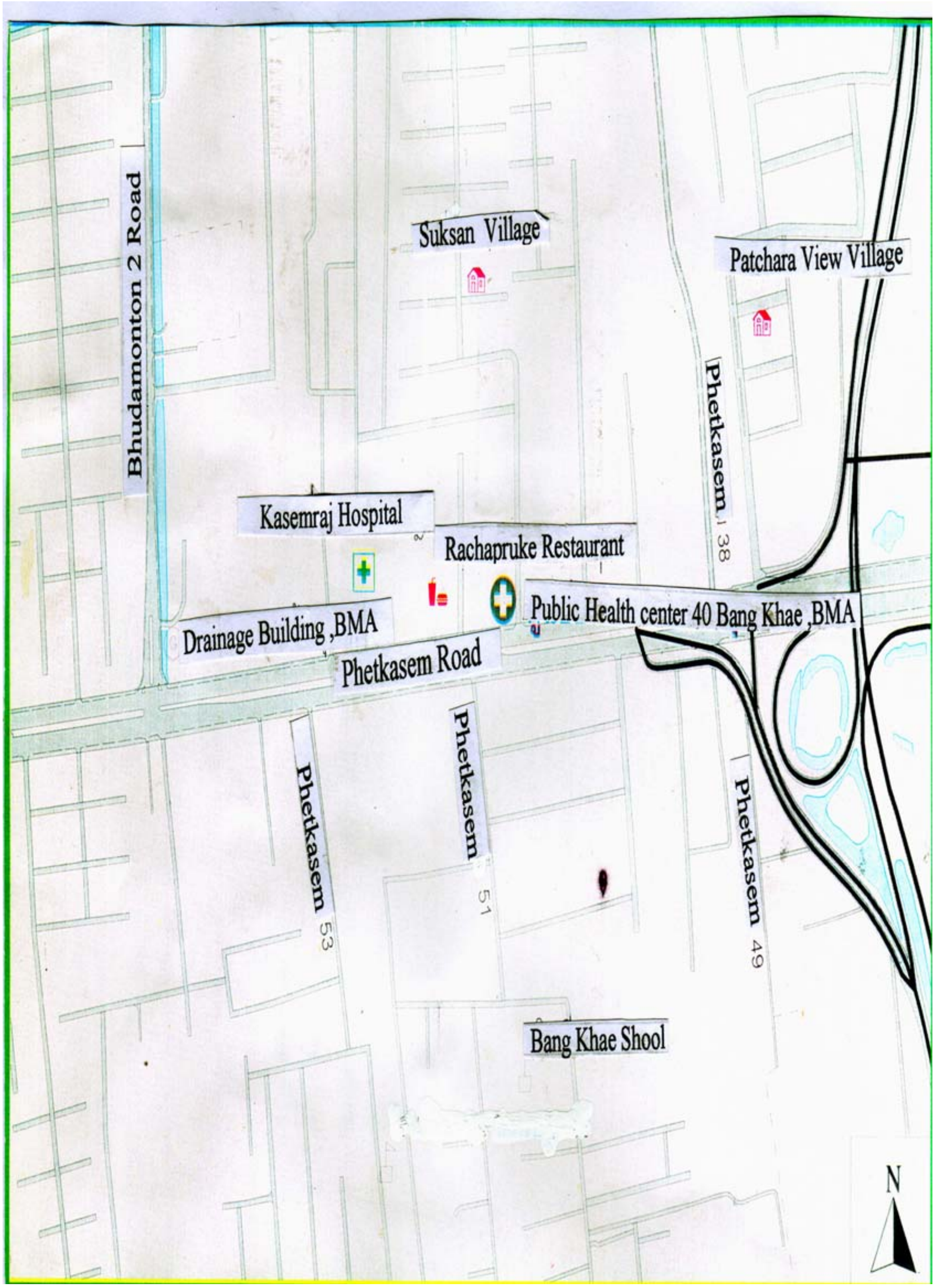


Figure 26 Phetkasem 51 Road map

The people opinion surveys (30 persons, person a house), done within people who live in the houses closed to group of factory are more than 10 years and most of them stay at home almost everyday in one week to identified condition problem in people's opinion recently ,the result found that some people (17 persons) inform that there is annoyance caused by odor and fog emitted from the smoke stack but some people (7 persons) inform they had not notice that problem and others (6 persons) inform that the problem was uncertain because there were few foundry left and they operated in limited time a day compare to 2-3 years ago. However, they still insisted that they saw the black smoke was emitted from the stack but it is not often.

In addition in this has set up audiometric test which try to find abnormal hearing, hearing loss in some student (20) by health department nurse team, the result found that normal the detail show in figure 27

Figure 27 People's companion

1.3 The Efficiency of Air Pollution Control System review

The basis data of all 5 factories had the air pollution control system, complied to the factory law 2525, B.E., wet scrubber but without any media inside, other name is gravity spray tower which it is simplest type of scrubber. In a spray Tower, particulate laden air passes in to a chamber where it contacts a liquid spray produced by spray nozzle. The tower placed in both vertical and horizontal waste gas flow paths.The liquid spray can be directed counter to gas flow, in the same direction as the gas flow,or perpendicular to the gas flow.The scrubber structures are similar and and used to treat emissions for more ten years. All of factories's owner only assign to some worker operate spray tower while working but spray tower have found widespread use in small foundry factory in Bangkok due to it have lower capital cost than other wet scrubbers. Also,spray towers generally have lower power consumption, so operating costs are also lower.Figure 28 show wet scrubber's diagram and figure 28 show wet scrubber's structure.

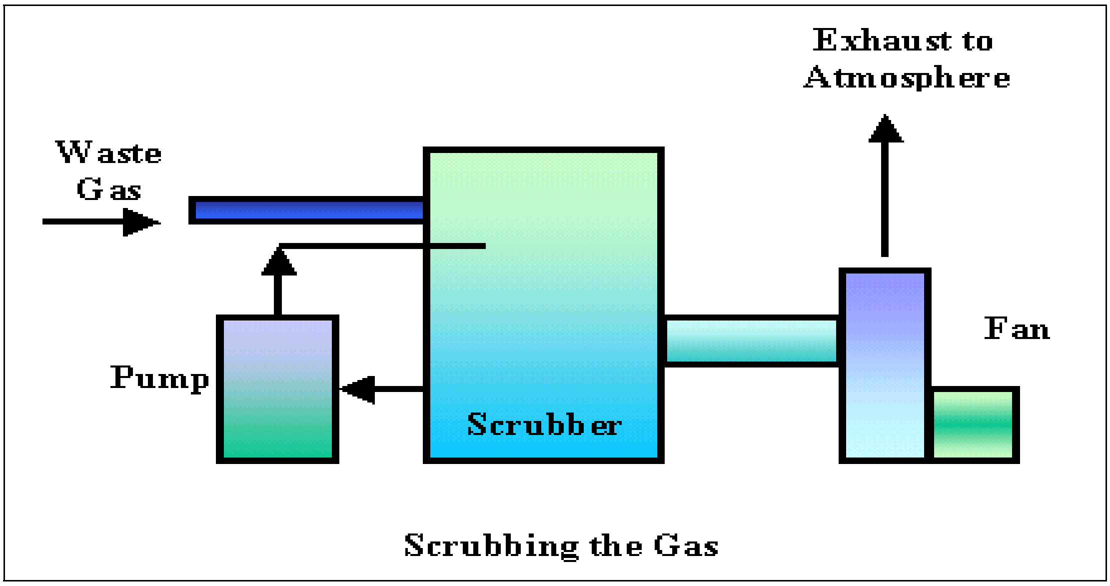


Figure 28 Wet scrubber's diagram

Figure 29 Wet Scrubber's structure

The efficiency of air pollution control system; wet scrubber review from 1) the basis data survey, such as the influents of the efficiency of air pollution control system, resulted that floating hood type could not collect the pollutant as efficiency as enclosure Hood. Additionally, some broken facilities of hood caused pollution control system were low efficiency ,and crowded of smoke and dust cover the work place area,amouth of water usage in wet scrubber to good contact between liquid and gas need liquid distribution normally liquid to gas ratio in spray tower is more than 2 liters /m^3 but from survey result water usage in spray tower were average 2 m^3/day and other activities average 1.5 m^3/day when classified by Industrial Act 2535 B.E. this water usage is very low it does not need water treatment system. the detail shown in Table 19

Table 19 Wet scrubber's data

Foundry Factory	Hood Description	Commendation	Physical structure	Water usage(m^3/d)
NO.1	Enclosure Hood with a big hole.	Incorrect	Vaned scrubber	3.5
NO.2	Aluminums furnace with Enclosure Hood	Incorrect	Vaned scrubber	2.30

Table 19 (Continued)

Foundry Factory	Hood Description	commendation	Physical structure	Water usage(m^3/d)
No.3	Receiving hood	Incorrect	Vertical tower	1.3
No.4	Enclosure Hood, a little smoke while working	Incorrect	Vaned scrubber	3.00
No.5	Enclosure Hood	Correct		2.5

The efficiency of air pollution control system; wet scrubber review from 2)the inspection survey on the efficiency of the air pollution control system which follow up Industrial Act 2535 B.E. by collecting its emission and analyzed for Total Suspended Particulate by the Department of Industrial Works and BMA in 2546, B.E. that mention before in methods part found the efficiency of all factories were in the range of 30-40 % pollutant treatment. Getting D and F grade by the Department of Industrial Works which meant it must have improve and needed emergency improve respectively, as the detail show in Table 20

Table 20 Foundry factories efficiency of air pollution control system.

foundry factories	**Date**	**Fuel type**	**Particulate Mater (mg/m^3)**	**Efficiency Grade**
NO.1	19 November	Coke	1920	F
NO.2	14 November	Kerosine	470	D
NO.3	19 November	Coke	1670	F
NO.4	9 October	Coke	680	D
NO.5	14 November	Kerosine	564	D
Industrial Source Emission standard			320 mg/m^3	

Source: Department of Health **,** BMA (2003)

The emission tests in 2546 B.E, found that the foundry operation conducted the pollution to people who live nearby. Air Pollution Control System emitted smoke which higher level than the regulation allowance. Sequently, the government sector had inform them to improve their system, however, that improve were not measure and the compliant by the people still remain.

On 24 to 31 may 2549 B.E. the survey by the government sector shown that the pollutant emission was reduced, comparred to the 2546 B.E. survey, however there were 2 factories emitted CO level higher than the standard. The table 21 shows the emission concentration in each factory.

Table 21 Stack Emission Testing Result (Outlet)

Foundry factory	Fuel	Pollutant Concentration			Compare with regulars
		CO	NO_X	SO_2	
NO.1	Coke	2,300	32	5	CO over standard
NO.2	Kerosene	18.3	1.2	Non detectable	Not over standard
NO.3	Coke	4143.2	29.2	2.1	CO over standard
NO.4	Coke	448.0	19.5	1.4	Not over standard
NO.5	Kerosene	207	6.4	5.3	Not over standard
standard		690	400	700	

Source: Health Department, BMA (2006)

The additional survey in 2550 B.E, found that Foundry Factory NO.5 had changed to use the electricity furnace resulted the reduction of CO NO_X and SO_2 concentration.

Additionally, the study of air pollution control system efficiency showed that all 5 foundry factories had faced the particulate matter problem. But only 2 foundry factories had CO level high over the standard, which the incomplete burning and Air

Pollution Control system are main causes. Since they had old technology the researcher could not evaluate the air pollution control system efficiency by using the static pressure drop or liquid flow rate, only pH and turbidity of liquid in wet scrubber that can be used. And when consider a level of problem situation from particulate matter which disturb and may be cause bad effect to worker show that most of all 5 foundry factory are in extreme impacted level and need improvement (table 20) but in 2551 B.E, measurement gas inlet and gas outlet (focus on 3 foundry factory which emission rate were high) found that SO_2 level were dominance increase from the past both inlet and outlet shown in table 22 and in 2550 B.E. ,toxic gas measurement was set up in 5 foundry factory work place area,15 sampling points to find out iron oxide which is importance pollutant in foundry process, but laboratory result show that nondetectable concentration due to it is not stable substance and others inspection to abate people's trouble is sound level measurement at people's house and Bangkhae School found that sound level (1 Leq1 hour) was 60 dB(A) when compare with background noise (51 dB (A)) it was not disturbed noise.

When we consider about impacted level of particulate matter which emitted from all 5 foundry factory (table 21) found that 4 of 5 foundry factories have extreme impaction means 4 foundry factories particulate matter level doesn't only over industrial source standard normally but in some foundry factory particulate level over standard to 6 times ,only one foundry factory have particulate matter level lower than standard 0.1 times, low impaction.

Table 22 Impact level with pollutant concentration level

Foundry Factory	Particulate Matter (mg/m3)	Pollutant Level Compare with standard	Impacted Level
No.1	1,920	Higher than standard 6 times	Extreme impaction
No.2	470	Higher than standard1.4 times	Extremes impaction
No.3	1670	Higher than standard 5.2 times	Extremes impaction
No.4	680	Higher than standard 2 times	Extremes impaction
No.5	20	Lower than standard 0.1 times	Low impaction

Table 23 Stack Emission Testing Result 2008

Foundry Factory	Concentration						
	Inlet gas			Out let gas			
	CO	SO_2	NO_X	CO	SO_2	NO_X	TSP
No.1	6490	407	2	1677	244	-	1,397
No.3	380	214	-	120	104	Less than 0.5	399
No.4	513	475	-	513	320	Less than 0.5	209

In this study have take stack emission testing all 4 times, 3 times undertaken by research and other was set up by other BMA officer (the first testing was set up on 2003,second was 2006,third was 2007,forth 2008) found that 3 foundry factories which was focus due to CO concentrated level in 2006 remain over the standard that mention before found that trend of pollutants concentration level,CO and SO_2 in 3 first order are decrease but on 2008 ,the last testing found that CO and SO_2 concentration level is coming increase level.

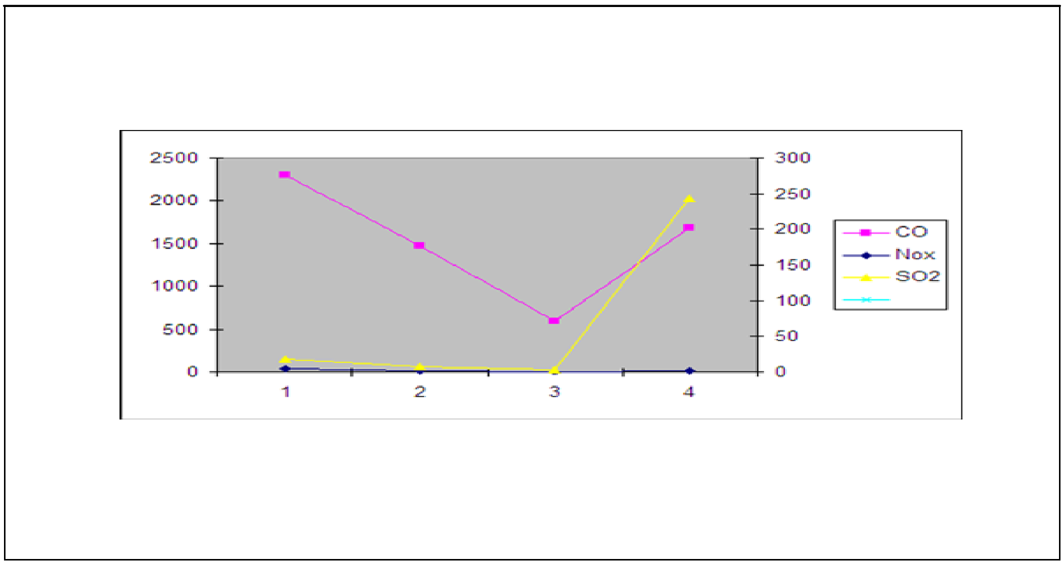


Figure 30 Summary of stack emission testing result foundry factory No.1

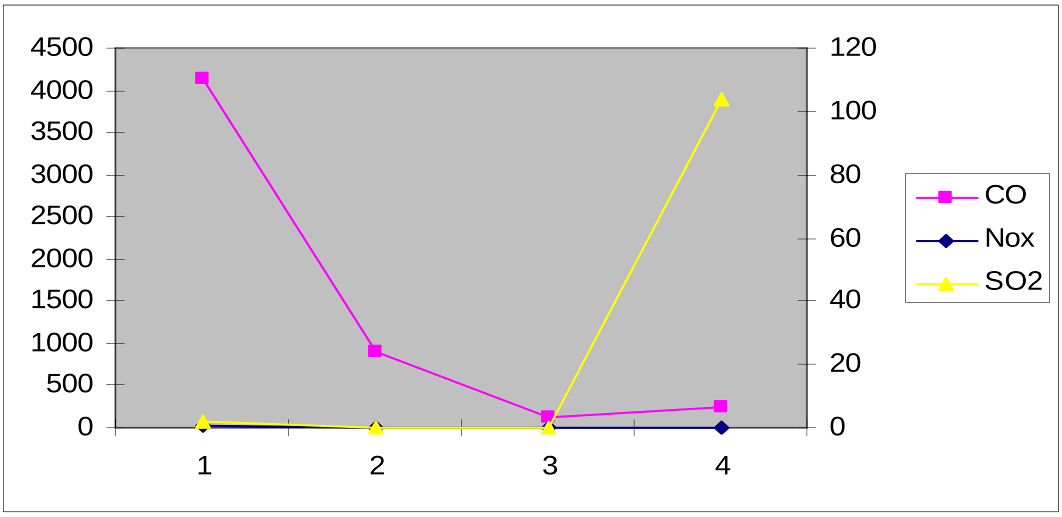


Figure 31 Summary of stack emission testing result foundry factory No.3

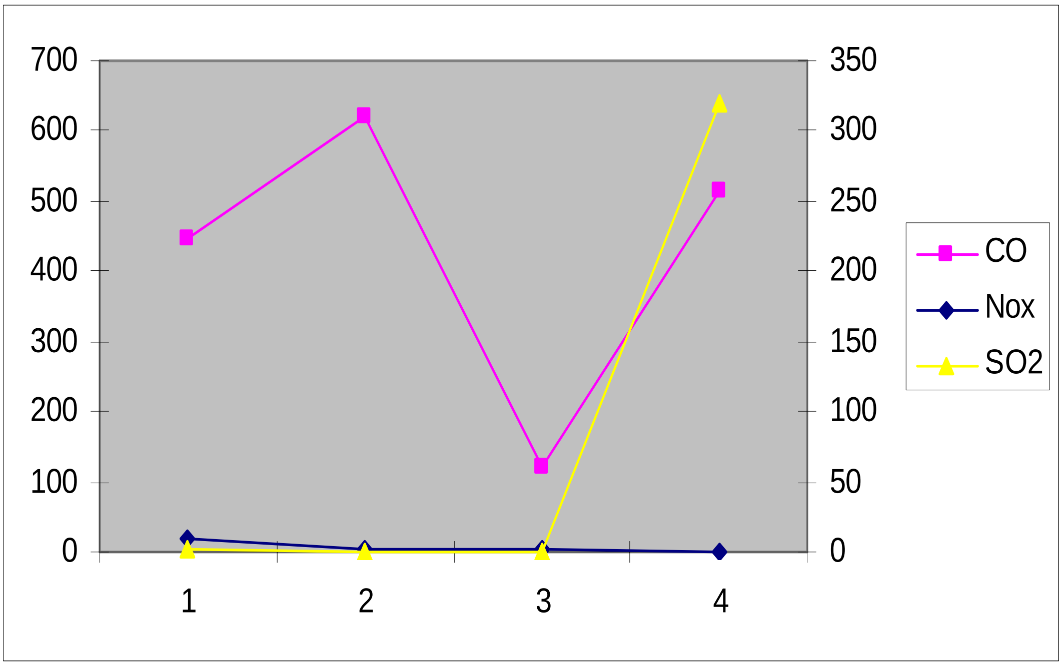


Figure 32 Summary of stack emission testing result foundry factory No.4

2. Air Quality Measurement

2.1 Air measurement in the of compliant 's house

The air measurement results in the house area that had complaints (locate at number 455/20 and 457/20) found that total dust and respirable dust was higher than standard, the detail in the Table 24 to 27 shown CO, NO_X ,SO_2 in average value this following.

Table 24 Ambient Air Quality at complaint house 455/20, in 2006

Date	Air Pollutant					Compare with standard
	TSP	PM 10	CO	NO_X	SO_2	
24May	0.19	0.11	1.20	0.13	0.025	PM 10 close to standard
25May	0.22	0.13	3.61	0.41	0.023	PM 10 higher than standard
26May	0.33	0.18	4.12	0.15	0.021	TSP and PM 10 higher Than standard
27May	0.77	0.33	7.13	0.15	0.021	TSP and PM 10 higher Than standard
28May	0.41	0.16	5.12	0.13	0.029	PM10 higher than standard
29May	0.37	0.23	3.87	0.12	0.019	TSP and PM 10 higher Than standard
30May	0.31	0.20	3.71	0.12	0.022	PM10 higher than standard
Average	0.39	0.22	4.98	0.13	0.022	TSPand PM 10 higher than standard
Standard	0.33	0.12	30	0.17	0.12	

Table 25 Ambient Air Quality maximum and minimum value at complaint house 455/20, 2006

Date	CO		NO_X		SO_2	
	min	max	min	max	min	max
24 May	0.77	3.00	0.017	0.27	0.025	-
25 May	0.72	4.25	0.075	0.60	Non detectable	0.023
26 May	0.82	7.00	-	0.15	Non detectable	0.021
27 May	1.45	10.00	0.021	0.20	0.017	0.024
28 May	1.02	7.00	0.078	0.32	0.015	0.034
29 May	0.32	6.00	0.1	0.25	0.011	0.033
30 May	2.42	5.27	0.1	0.41	Non detectable	0.022

Table 26 Ambient Air Quality at complaint house number 457/20

Date	Air Pollutant					Compare with standard
	TSP	PM 10	CO	NO_X	SO_2	
24 May	0.20	0.09	1.00	0.02	0.020	All parameters does not over standard
25 May	0.16	0.08	2.12	0.03	0.010	All parameters does not over standard
26 May	0.27	0.13	3.01	0.11	ND	PM10higher than standard
27 May	0.56	0.32	5.11	0.9	ND	TSP and PM 10 higher than standard
28 May	0.21	0.14	2.20	0.2	0.014	PM10 higher than standard
29 May	0.34	0.23	0.70	0.1	ND	TSP and PM 10 higher than standard
30 May	0.34	0.14	0.71	0.1	0.019	PM 10 higher than standard

Table 26 (Continued)

Date	Air Pollutant					Compare with standard
	TSP	PM 10	CO	NO_X	SO_2	
Average	0.31	0.16	2.12	0.20	0.012	TSP close to standard and PM 10 higher than standard
Standard	0.33	0.12	30	0.17	0.12	

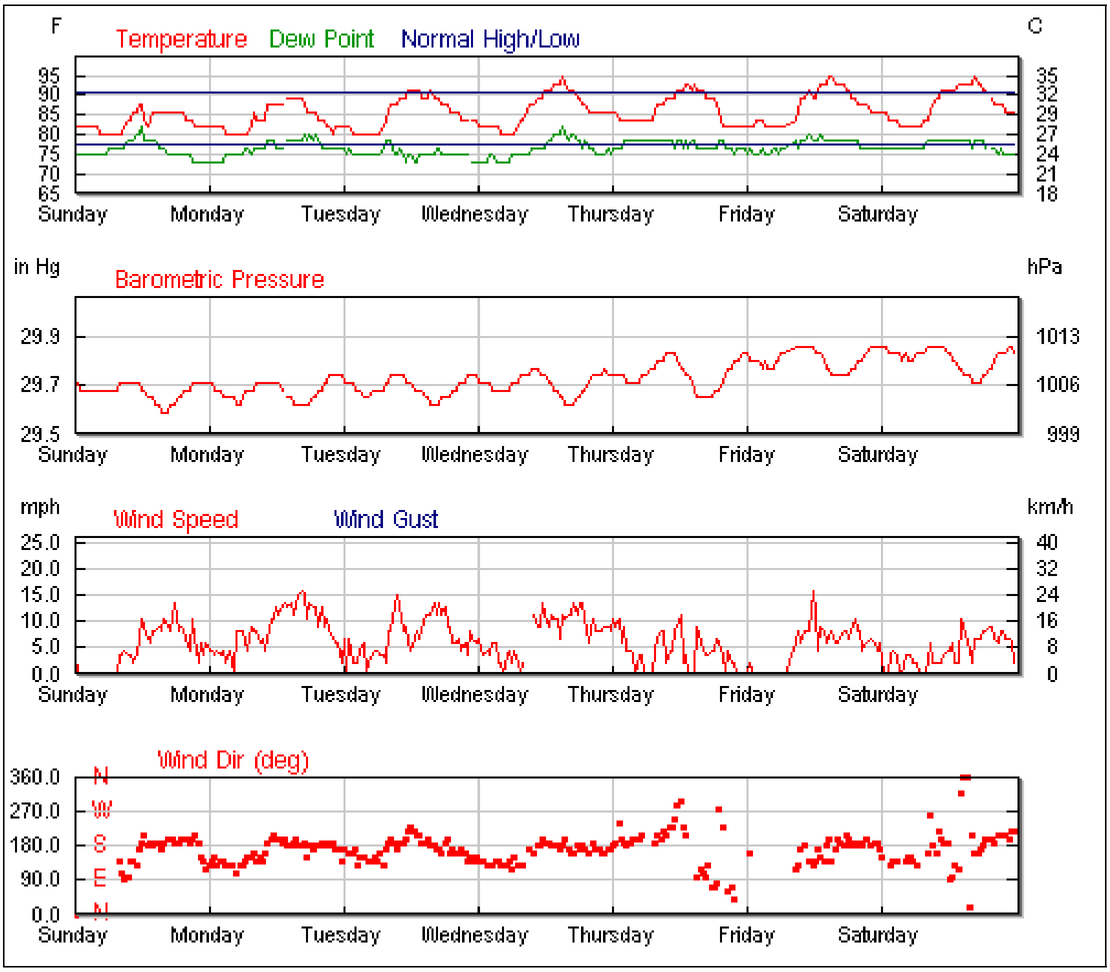


Figure 33 Weekly meteorology data 1

Conclusion ,the air qualities in both houses with complaint are similar high first house ,TSP maximum value is 0.77 mg/m ^{3} ,minimum value is 0.22 mg/m ^{3} average is 0.39 mg/m3 and in the second house TSP maximum value is 0.56 mg/m ^{3} ,minimum value is 0.22 mg/m ^{3} and average is 0.31 mg/m^3. Both are higher than standard level and also the PM $_{10}$

2.1 Air measurement results in Bang kare Nueng Sang Wan School

Bangkhare Nueng Sang Wan School is the primary school located in the upwind but there were records in 2546 B.E., that the smoke from the factories accidentally emit from the stack and crowded all over school area , many students had sick with symptoms like nuasia ,fiath and needed to transfer to hospital. Therefor it is included in the sensitive point by this problem also. The air measurement results in the school are below.

Table 27 Ambient Air Quality at Bangkhae Nueng Sang Wan School 2006

Date	Air pollutant					Compare with standard
	TSP	PM 10	CO	NO_X	SO_2	
1 June	0.15	0.05	0.07	0.07	ND	The TSP average
2 June	0.14	0.04	0.61	0.05	0.04	was close to standard
3 June	0.28	0.11	0.10	0.11	ND	and PM 10 average
4 June	069	0.29	0.11	0.04	0.014	was higher than
5 June	0.37	0.14	1.11	ND	0.014	standard
6 June	0.34	0.20	2.24	ND	ND	
7 June	0.27	0.11	2.01	0.03	ND	
Average	0.32	0.13	0.13	0.04	0.006	
Standard	0.33	0.12	30	0.17	0.12	

Remark: mg/m^3 is unit for TSP and PM10

ppm is unit for CO,NO_X ,SO_2

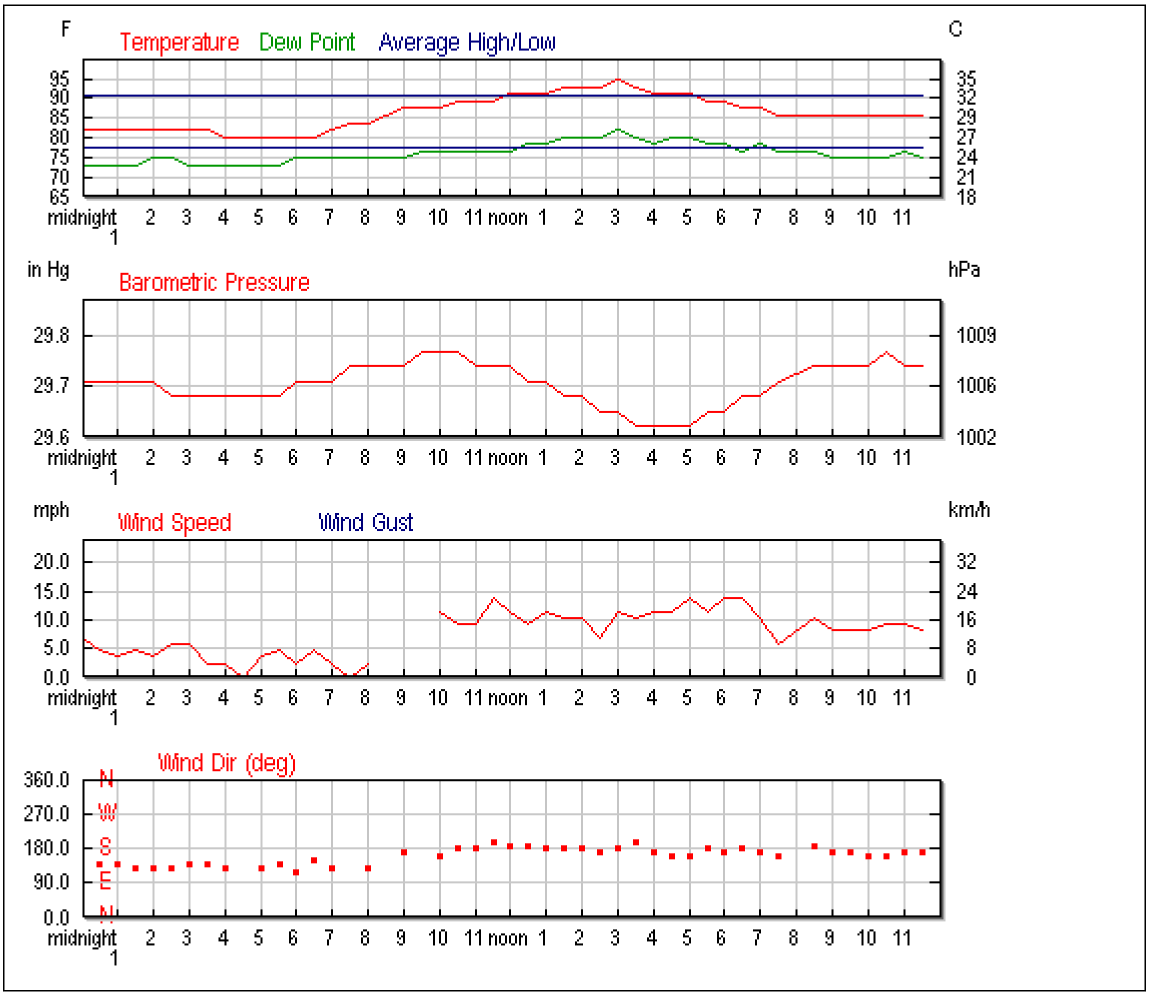


Figure 34 Weekly meteorology data 2

The air quality in Bangkhare Nueng Sang Wan School, total suspended Particulate was below the standard but close and small particulate was higher than standard level as in the house with complaint. However, since the school locates upwind and has more distance, the houses would have more trouble and when consider about present (2551 B.E.) air pollution problem condition on community area found that TSP and PM 10 remain high and close to standard and NOx and SO_2 level close to standard for resident zone too.

Table 28 Air quality on community 2551 B.E.

Pollutants	House 1	House 2	Bangkhae School	**Standard**
TSP (mg/m^3)	**0.39**	**0.31**	**0.32**	**0.33**
PM10(mg/m^3)	**0.22**	**0.16**	**0.13**	**0.12**
CO (ppm)	**4.98**	**2.12**	**0.10**	**30**
NOx (ppm)	**0.17**	**0.20**	**0.04**	**0.17**
SO_2 (ppm)	**0.12**	**0.012**	**0.006**	**0.12**

2.3 The Ambient air at Phetkasem Soi 51 Road Bangkare the day without working of foundry factory, April 2551 B.E.

The survey and measurement for around Phetkasem 51 Road,outside factory area used toxic gas analyzer found that SO_2 was high concentration even though it was the day with out foundry factory's working. From surrounded area survey does not found other industrial source which produce SO_2 except the rest foundry factory and the mobile source (vehicles) due to it is a very traffic jam area.This result means to Phetkasem 51 Road is faced on SO_2 high background area even though the day without foundry factories 's working.

Table 29 Ambient Air measurement results ,SO_2 on Petchakasem Road 51

Area	Average value (ppm)
The small road infront of Bangkhare School	
Point 1 Point 2 Point 3	3.50
The area which near small factory	8.00
The small road in front of Thai Roung Ruang Foundry Factory	10.00
Roadside opposite Kasem Raj Hospital	10.00

2.4 Risk Assessment

From Air measurement in the of both compliant 's house and Bangkhae Scholl which found that some pollutant were high concentration level so to monitor on people and student health effect which expose risk factor for long time due to they live in Phetkasem 51 Road for long time ,researcher try to evaluate by risk assessment, the detail show this following

Using the data from table 24, the Hazard Index (HI) of each pollutant topeople who live in the complaint house (455/20) could be calculated as below.

HI for Total Suspended Particulates (TSP)

= TSP Concentration in the Ambient / TSP Ambient Standard

= $0.39 \text{ mg/m}^3 / 0.33 \text{ mg/m}^3$

= 1.18

HI for PM-10

= PM-10 Concentration in the Ambient / PM-10 Ambient Standard

= $0.22 \text{ mg/m}^3 / 0.12 \text{ mg/m}^3$

= 1.83

HI for CO

= CO Concentration in the Ambient / CO Ambient Standard

= 4.98 ppm / 30 ppm

= 0.17

HI for NO_2

= NO_2 Concentration in the Ambient / NO_2 Ambient Standard

= 0.13 mg/m^3 / 0.17 mg/m^3

= 0.17

HI for SO_2

= SO_2 Concentration in the Ambient / SO_2 Ambient Standard

= 0.022 mg/m^3 / 0.12 mg/m^3

= 0.18

Total Hazard Index = 1.18 + 1.83 + 0.17 + 0.17 + 0.18 = 3.53

Conclusion, people who live in this house might get very small risk (only small number higher than 1) of the air pollutants especially the small particulate that might cause some health problems on respiratory system.

Using the data from table 26, the Hazard Index (HI) of each pollutant to people who live in the complaint house (457/20) could be calculated as below.

HI for Total Suspended Particulates (TSP)

= TSP Concentration in the Ambient / TSP Ambient Standard

= 0.31 mg/m^3 / 0.33 mg/m^3

= 0.94

HI for PM-10

= PM-10 Concentration in the Ambient / PM-10 Ambient Standard

= 0.16 mg/m^3 / 0.12 mg/m^3

= 1.33

HI for CO

= CO Concentration in the Ambient / CO Ambient Standard

= 2.12 ppm / 30 ppm

= 0.07

HI for NO_2

= NO_2 Concentration in the Ambient / NO_2 Ambient Standard

= 0.20 mg/m^3 / 0.17 mg/m^3

= 0.18

HI for SO_2

= SO_2 Concentration in the Ambient / SO_2 Ambient Standard

= 0.012 mg/m^3 / 0.12 mg/m^3

= 0.1

Total Hazard Index = 0.94 + 1.33 + 0.07 + 0.18 + 0.1 = 2.62

Conclusion, people who live in this house might get very small risk (only small number higher than 1) of the air pollutants also especially the small particulate that might cause some health problems on respiratory system.

Using the data from table 27, the Hazard Index (HI) of each pollutant to student who spent their time in the school could be calculated as below.,Give

1) Average time that student spent in the school = 8 hours/day

2) Average student bodyweight for primary school (7 – 12yrs) = 25 kg

Reference Dose Adjustment.Normally the standard is calculated from adult with 70 kg bodyweight and 24 hours a day, therefore reference dose should be changed.

Adj. RFD = Standard Conc. * (25/70)

Adj. RFD for Total Suspended Particulates (TSP)

= TSP Ambient Standard * (25/70)

= 0.33 mg/m^3 * (25/70)

= .0.11 mg/m^3

Adj. RFD for PM 10

= PM10 Ambient Standard * (25/70)

= 0.12 mg/m^3 * (25/70)

= .0.04 mg/m^3

Adj. RFD for CO

= CO Ambient Standard * (25/70)

= 30 ppm* (25/70)

= 10.71 ppm

Adj. RFD for NO_2

= NO_2 Ambient Standard * (25/70)

= 0.17 mg/m^3 * (25/70)

= 0.06 mg/m^3

Adj. RFD for SO_2

= SO_2 Ambient Standard * (25/70)

= 0.12 mg/m^3 * (25/70)

= 0.04 mg/m^3

HI for TSP

= TSP Conc. in Ambient * (8 hours/24 hours) /Adj. RFD for TSP

= 0.32 mg/m^3 * (8 hours/24 hours) /.0.11 mg/m^3

= 0.96

HI for PM-10

= PM-10 Conc. in Ambient* (8 hours/24 hours) /Adj. RFD for PM-10

= 0.13 mg/m^3 * (8 hours/24 hours) /0.04 mg/m^3

= 1.08

HI for CO

= CO Conc. in Ambient* (8 hours/24 hours) /Adj. RFD for CO

= 0.13 ppm * (8 hours/24 hours) /10.71 ppm

= 0.004

HI for NO_2

= NO_2 Conc. in Ambient* (8 hours/24 hours) /Adj. RFD for NO_2

= 0.04 mg/m^3 * (8 hours/24 hours) /0.06 mg/m^3

= 0.2

HI for SO_2

= SO_2 Conc. in Ambient* (8 hours/24 hours) /Adj. RFD for SO_2

= 0.006 mg/m^3 * (8 hours/24 hours) /0.04 mg/m^3

= 0.05

Total Hazard Index = 0.96 + 1.08 + 0.004 + 0.2 + 0.05 = 2.29

Conclusion, student in the school might get very small risk (only small number higher than 1) by intake of the air pollutants also especially the small particulate that might cause some health problems on respiratory system.

3. Redesign Air Pollution Control System and facilities, Packed Column

There are three reasons which conduct redesign a new air pollution control system to remove SO_2 ,TSP and CO due to SO_2 is acid gas ,it is high risk in acute effect to people who exposed especially young student in Bang khare School.
The reason that mention are this following

1. The stack emission testing results, SO_2 concentration level in stack emission still lower than The Emission Standard which enforce by Industrial Works Department, Industrial Works Act 2535 the B.E. but the SO_2 concentration level on 2008 is in dominate high level even though it doesn't over the same standard.
It means air pollution system efficiency return to low again.

2. CO and TSP concentrated level in stack emission on 2006-2008 remain higher than The Emission Standard which enforce by Industrial Works Department, Industrial Works Act 2535 the B.E. compare with CO and TSP concentrated level in stack emission on the initial stage ,after government enforcement (2003-2006)

3. The ambient air quality in the complain 's house and surrounding area on 2006-2008 TSP and PM_{10} concentration level in both complain 's house found that sometimes were higher than The ambient air standard, Pollution Control Department,Promote and quality environment 2553 B.E. and other close to same standard and,it has never under standard and SO_2 background level in some area on the day with out foundry factories 's working were higher than The ambient air standard, Pollution Control Department, Promote and preventive quality environment 2553 B.E. also in this result can predict that SO_2 background level emitted from other source .

From the reason that mention emission control from industrial source is one of way to prevent acute adverse effect from SO_2 which it ever have occur on 2005, 50 students have a nausea and headache due to there were very high SO_2 concentration level in school area. Next past will mention to decrease SO_2,TSP and CO by "Packed Column" because of its ability to effectively remove particulates and gaseous pollutants. Table 30 show equipment's description compare between wet scrubber and packed column

Table 30 Equipment's description of wet scrubber and packed column

Topic	Wet Scrubber	Packed Column
Liquid spraying to small droplet	Spray Nozzle	Spray Nozzle, media
Circulating Pumping	Use high pressure pump than Packed Column	Use low pressure pump
Air Pollution Control System weigh	Less than Packed Column	More weight than wet scrubber
Exhausting Fan	Lower pressure than packed column	Higher pressure than wet scrubber
Fouling	Spray Nozzle	media

Equipment description:Packed Column,used for the continous contact of liquid and gas,are usually vertical columns which have been fill with packing or devices of large surface area.The liquid is distribute over and trickles down through the packed bed,thus exposing a large surface area to contact gas the countered in gaseous pollutant control for the removal of the undesirable gas, vapor or odor.

The gas stream moves upward through the packed bed against and absorbing or reaching liquor (solvent-scrubing solution) which is injected at the top of the packing.This result in the highest possible efficiency. Since the solute concentration in the gas stream decrease as it rises through column, there is constantly fresher solvent available for contact. This provides the maximum average driving force for the diffusion process throughout the packed bed, figure 33 show packed column structure

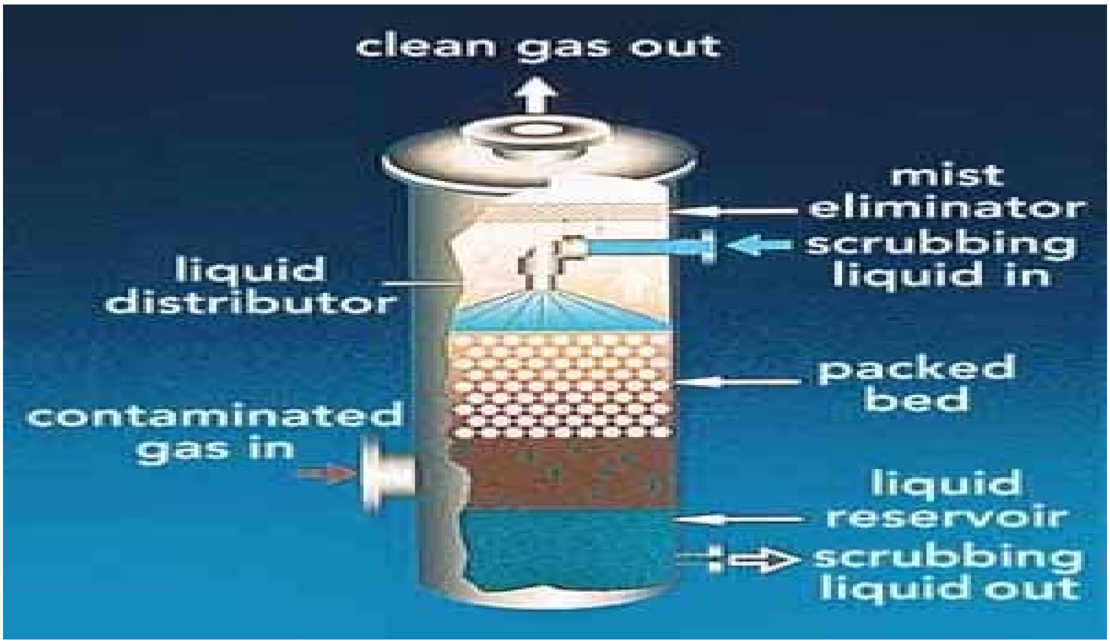


Figure 35 Packed column structure

Principle to design packed column ,the engineering design of gas absorption equipment must base on a sound application of the principles of diffusion, equilibrium, and mass transfer, The parameters effective overall performance of system are type and composition of gases, waste gas flow rate ,temperature and humidity, gas velocity and pressure drop, liquid to gas ratio and solvent(water is used as it is very inexpensive and plentiful) which consider its property.

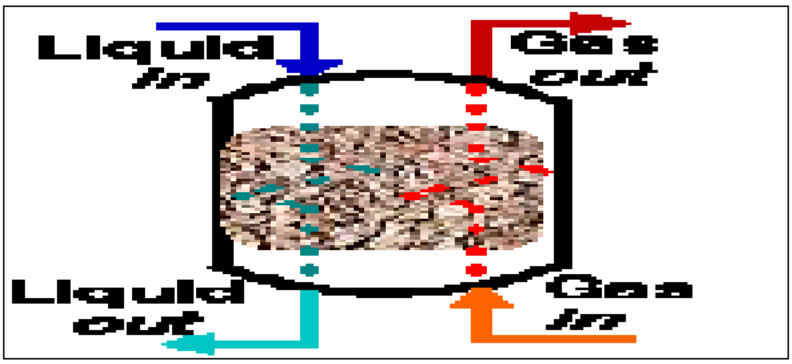


Figure 36 Balance mass transfer

3.1. Foundry Factory No.1

Emission Rate of SO_2 from average fuel usage,coke = 41.16 ton/year (0.00190 ton/hr.) 3 % by weight sulfur is composition of coke in combustion process sulfur was reduce to SO_2 complete (without SO_3)

Sulfur $= \frac{0.00190}{hr} \times \frac{3S}{100 \text{ lb m cool}}$

$= 0.000057$ ton/hr

Sulfur in mol/hr

Sulfur in mol / hr;S/hr mol

$= \frac{0.000057 \text{ ton}}{hr} \times \frac{1{,}000{,}000 \text{ g}}{ton} \times \frac{\text{mole S}}{32 \text{ g}}$

$= 1.781$ mole S/hr

Emission Rate of SO_2 in hour

S mole to SO_2 $= \frac{1.781 \text{ mole S} \times 1}{hr}$

$= 1.781$ mole SO_2/hr

$= \frac{1.781 \text{ mole } SO_2}{hr} \times \frac{64 \text{ g}}{\text{mole } SO_2}$

$= 113.9$ g/hr

$= 0.000139$ ton SO_2/hr

Gas stream flow rate from foundry factory's data

Gas Velocity = 11.32 m/s

= 11.32 x 3.281

= 37.14 ft/s

Stack diameter = 0.20m

Area of stack $= 3.14 r^2$

$= 3.14(0.1)^2$

$= 0.031 m^2$

$= 0.031 \times 10.76$ ($m^2 \times 10.76 = ft^2$)

$= 0.333 f^2$

Then gas stream flow rate = 37.14 ft /s x 0.333 ft^2 x 60

=742 ACFM

Packed Column Design,The operating condition are

1. Remove SO_2 from stream gas ;90 % is to be collected
2. The Unit Operate 60 % of the flooding gas mass velocity (assume)
3. The actual liquid flow rate is 20 % more than the minimum
4. Gas stream 742 ACFM
5. SO_2 concentration in inlet gas stream 1.139 mol %
6. Scrubbing liquid = pure water ;packing type 2 in
7. Pall Ring (plastic);H_{GO} of the column = 3 ft;Packing factor = 40
8. Henrry's law constant ;m = 1.20
9. Density of gas (air) = 0.075 lb/ft^3
10. Density of water = 62.4 lb/ft^3
11. Inlet gas temperature 49 C (49 C +17.78 x1.8=120 F)
12. Viscosity of water =1.8 cP
13. Stack flow rate = 30

Calculation;First calculate equilibrium outlet liquid composition ,and the outlet gas composition for

x^* = y1/m ;when y is mole fraction of gas

m is Henrry's law constant

x^* is mole fraction of solution in liquid

$$= \frac{0.011}{1.20}$$

= 0.0132

y_2 = (0.1)y1 /((1-y1)+(0.1)y1)

= 0.1(0.0132) / ((1-0.0132)+(0.1)(0. 0132))

= 0.00132/ (0.9868 +0.00132)

= 0.00132 / 0.98812

= 0.00133

The minimum liquid to gas ratio (molar basic)is obtained by material balance

$(Lm/Gm)min = (y_1-y_2) / (x_1-x_2)$

$= (0.011-0.00133) / (0.0132-0)$

$= 0.00967 / 0.0132$

$= 1.7325$

The actual ratio is 25 % above the minimum thus

$Lm/Gm = (1.25) (Lm/Gm)min$

$= (1.25) (0.7325)$

$= 0.915$

Two parameter are needed to use the Colurn Chart to evaluate N_{OG}

$(y_1-mX_2) / (y_{2-} mX_2) = (0.011-(1.2)(0)) / (0.00132-(1.2)(0))$

$= 0.011/0.00132$

$= 8.3$

$(mGm)/Lm = 1.2 /0.7325$

$= 0.879$

From Colburn's Chart N_{GO} of transfer units, N_{GO}

$N_{GO} = 6.8$

The packing height is thus

$Z = (N_{GO}) (H_{GO})$

$= (6.8)(3)$

$= 20.4$ ft

From "Generalized pressure drop correlation to estimate column diameter figure" is employed to calculate the tower diameter and packing pressure drop

$(L/G)(\rho / \rho_1)^{0.5} = (Lm/Gm) (64.06/29) (0.075/62.4)^{0.5}$

$= (0.915)(2.208)(0.034)$

$= 0.06$

From "Generalized pressure drop correlation to estimate column diameter figure'

$(G^2 F\psi u_L^{0.2}) / (\rho_l \rho_{gc}) = 0.005$

Thus the flooding velocity is

$Gf =(0.005) (\rho_l \rho g_c)/ (F\psi u_L^{0.2})^{0.5}$

$= ((0.005) ((\rho_l ps \ \rho_c) / (F\psi u_L^{0.2}))^{0..5}$

$$= \left[\frac{(0.005)(30)(62.4)(0.075)}{(40)(2)(1.8)^{0.2}}\right]^{0..5}$$

$$= \left[\frac{0.702}{89.6}\right]^{0.5}$$

$$= 0.88 \text{ lb/ft}^2\text{/sec}$$

The actual velocity is

G act = (0.6)(0.088)

= 0.052 lb/ft ^{2}/sec

= 190 lb/ft ^{2}/hr

The tower diameter may now calculate directly from equation

Dt = (1.13) (S) $^{0.5}$ when S = q(acfm)/4

S = 742/60

= 12.3

= 12.3/4

=3.075 acfs

Dt = 1.13(3.075)$^{0.5}$

= 1.13 (1.75)

= 1.97 ft

The packing height is 20.4 ft

The tower diameter is 1.97 ft

3.2. Foundry Factory No.3

Calculate from same the operating condition like Foundry Factory No.1 except these input data

1. Gas mass flow rate 1150 ACFM
2. SO_2 concentration in inlet gas stream 11.25 mol %
3. Inlet gas temperature 62 C (62 C +17.78 x1.8=143.6 F)
4. Rasching ring ;H_{GO} of the column = 2 ft

Calculation;Emission Rate of SO2 from average fuel usage,coke = 70.56 ton/year (0.012 ton/hr.) 2% by weight sulfur are composition of coke, assume in Combustion process sulfur was reduce to SO_2 complete(without SO_3)

Sulfur $= \frac{0.00816}{hr} \times \frac{2s}{100 \text{ lb m cool}}$

$= 0.0001632$ ton/hr (0.1632 kg/h)

mol/hr Sulfur

S/hr mol $= \frac{0.0001632 \text{ ton}}{hr} \times \frac{1,000,000 \text{ g}}{ton} \times \frac{\text{mole s}}{32 \text{ g}}$

= 5.10 mole S/hr

Emission Rate of SO_2 in hour ;S mole to SO_2

$= 5.10 \frac{\text{mole S} \times 1}{hr}$

$= 5.10$ mole SO_2 /hr

$= \frac{5.10 \text{ mole } SO_2}{hr} \times \frac{64 \text{ g}}{\text{mole SO2}}$

= 326.4 g/hr

= 0.000326 ton SO_2/hr

Gas stream flow rate from foundry factory's data

ACFM= Stack gas dry Volumetric flow rate in Actual Cubic Feet per Minute

= Gas Velocity (feet per second)x Area of stack or duct (square feet) x 60 (second per minute)

Gas Velocity =14.69 m/s

=14.69 x 3.281

= 48.14 ft/s

Stack diameter =0.22 m

Area of stack $= 3.14 r^2$

$= 3.14(0.11)^2$

$= 0.037 m^2$

$= 0.037 \times 10.76$ ($m^2 \times 10.76 = ft^2$)

$= 0.398 f^2$

Then gas stream flow rate = 48.14 ft /s x 0.398 ft^2 x 60

= 1150 ACFM

Packed Column Design ; First calculate equilibrium outlet liquid composition, and the outlet gas composition for

x^* = y1/m when y is mole fraction of gas

m is Henrry's law constant

x^* is Mole fraction of solution in liquid

$$= \frac{0.051}{1.20}$$

= 0.0425

y_2 = (0.1)y1 / ((1-y1)+(0.1)y1))

= 0.1(0. 051) /((1-0. 051)+(0.1)(0. 051))

= 0.0051 / (0.949 +0.0051)

= 0. 0051 /0.9541

=0.0053

The minimum liquid to gas ratio (molar basic) is obtained by material balance

(Lm/Gm)min = $(y_1-y_2) / (x_1-x_2)$

= (0.051-0.0053) / (0.0425 -0)

=0.0457 / 0.0425

= 1.075

The actual ratio is 25 % above the minimum thus

Lm/Gm = (1.25) (Lm/Gm) min

= (1.25) (1.075)

= 1.343

Two parameter are needed to use the Colurn Chart to evaluate N_{OG}

$(y_1-mX_2) / (y_2- mX_2)$= ((0. 0425) -(1.2)(0))/ (0.0053-(1.2)(0))

= 0.0425 /0.0053

= 8.00

(mGm)/Lm = 1.2/1.343

= 0.893

From Colburn's Chart

N_{GO} = 7.00

The packing height is thus

$Z = (N_{GO})(H_{GO})$

$= (7.0)(2)$

$= 14.00$ ft

From Generalized pressure drop correlation to estimate column diameter figure is employed to calculate the tower diameter and packing pressure drop

$(L/G)(\rho / \rho_1)^{0.5} = (Lm/Gm)(64.06/29)(0.075/62.4)^{0.5}$

$= (1.34)(2.208)(0.034)$

$= 0.1005$

From "Generalized pressure drop correlation to estimate column diameter "figure

$(G^2 F\psi u_L^{0.2}) / (\rho_l \rho_{gc}) = 0.14$

Thus the flooding velocity is

$Gf = (0.14)(\rho_l \rho g_c) / (F\psi u_L^{0.2})^{0.5}$

$$= \left((0.14)((ps\ \rho_l \rho g_c) / (F\psi u_L^{0.2} \right)^{0..5}$$

$$= \left(\frac{(0.14)(30)(62.4)(0.075)}{(160)(1)(1.8)^{0.2}} \right)^{0..5}$$

$$= \frac{19.656^{0..5}}{(160)(1.124)}$$

$= 0.109^{0.5}$

$= 0.330$ lb/ft ^{2}/sec

The actual velocity is

G act $= (0.6)(0.330)$

$= 0.198$ lb /ft ^{2}/sec

$= 712.8$ lb/ft ^{2}/hr

The tower diameter calculate directly from equation

$D_T = (1.13)(S)^{0.5}$ when $S = q(acfm)/4$

$S = 1150.7/60$

$= 19.116$

$= 19.116/4$

$= 4.79$

$D_T \quad = 1.13\ (4.79)^{0.5}$

$= 1.13\ (2.188)$

$= 2.47$ ft

Then the packing height is ft 14.00 ft and the tower diameter is 2.47 ft

3.3 Foundry Factory No.4

Emission Rate of SO_2 from average fuel usage,coke = 105.58 ton/ye (0.012 ton/hr.)3 % by weight sulfur, assume in combustion process sulfur was reduce to SO_2 completely

$$\text{Sulfur} = \frac{0.012}{\text{hr}} \times \frac{3S}{100 \text{ lb m cool}}$$

$= 0.0036$ ton/hr (0.36 kg/h)

Sulfur in mol/hr

Sulfur mol in hr;S/hr mol

$$= \frac{0.00036 \text{ ton}}{\text{hr}} \times \frac{1{,}000{,}000 \text{ g}}{\text{ton}} \times \frac{\text{mole S}}{32 \text{ g}}$$

$= 11.25$ mole s/hr

Emission Rate of SO_2 in hour ;S mole to SO_2

$$= \frac{11.25 \text{ mole S} \times 1}{\text{hr}}$$

$= 11.25$ mole SO_2/hr

$$= \frac{11.25 \text{ mole SO2}}{\text{hr}} \times \frac{64 \text{ g}}{\text{mole } SO_2}$$

$= 720$ g/hr

$= 0.00072$ ton SO_2/hr

Gas Stream Rate (ACFM)

ACFM= Stack gas dry Volumetric flow rate in Actual Cubic Feet per Minute

= Gas Velocity (feet per second)x Area of stack or duct (square feet) x 60 (second per minute)

Input Data Gas Velocity = 12.44 m/s

= 12.44 x 3.281

= 40.81 ft/s

Area of stack = 3.14 r^2 (Diameter 0.67)

= $3.14(0.335)^2$

= 3.14(0.112)

= 0.351 m2

= 0.351x10.76 (m^2x 10.76=ft^2)

= 3.776 f^2

Then gas stream flow rate = 40.81 ft/s x 3.776 f^2 x 60

= 9245.9 ACFM

Packed Column Design;The operating condition are

1. Remove SO_2 from stream gas ;90 % is to be collected
2. The Unit Operate 60 % of the flooding gas mass velocity (assume)
3. The actual liquid flow rate is 20 % more than the minimum
4. Gas mass flow rate 9245.9 ACFM
5. SO_2 concentration in inlet gas stream 11.25 mol %
6. Scrubbing liquid = pure water ;packing type 1in
7. Rasching ring ;H_{GO} of the column = 2 ft
8. Henrry's law constant ;m = 1.20
9. Density of gas (air) = 0.75 lb/ft^3
10. Density of water = 62.4 lb/ft^3
11. Inlet gas temperature 49 C (49 C +17.78 x1.8=120 F)

Calculation;First calculate equilibrium outlet liquid composition ,and the outlet gas composition for

$x = y1/m$ when y is mole fraction of gas

m is Henrry's law constant

x is mole fraction of solution in liquid

$$= \frac{0.1125}{1.20}$$

$= 0.093$

$y_2 = (0.1)y1 / ((1-y1)+(0.1)y1)$

$= 0.1(0.1125) / ((1-0.1125)+(0.1)(0.1125))$

$= 0.1125 / (0.8875+0.01125)$

$= 0.01125 / 0.89875$

$= 0.0125$

The minimum liquid to gas ratio (molar basic)is obtained by material balance

$(Lm/Gm)min = (y_1-y_2) / (x_1-x_2)$

$= (0.1125-0.0125) / (0.093-0)$

$= 0.1 / 0.093$

$= 1.075$

The actual ratio is 25 % above the minimum thus

$Lm/Gm = (1.25) (Lm/Gm)min$

$= (1.25) (1.075)$

$= 1.343$

Two parameter are needed to use the Colurn Chart to evaluate N_{OG}

$(y_1-mX_2) / (y_{2-} mX_2) = (0.093-(1.2)(0)) / (0.01251-(1.2)(0))$

$= (0.093-(2)(0))$

$= 7.43$

$(mGm)/Lm = 1.2 /1.343$

$= 0.893$

From Colburn's Chart

$N_{GO} = 8.5$

The packing height is thus

$Z \quad = (N_{GO})\ (H_{GO})$

$= (8.5)(2)$

$= 17.00$ ft

From Generalized pressure drop correlation to estimate column diameter.is employed to calculate the tower diameter and packing pressure drop

$(L/G)(\rho / \rho_1)^{0.5} = (Lm/Gm)\ (64.06/29)\ (0.075/62.4)^{0.5}$

$= (1.34)(2.208)(0.034)$

$= 0.1005$

From Generalized pressure drop correlation to estimate column diameter

$(G^2 F\psi u_L^{0.2}) / (\rho_l\ \rho_{gc}) = 0.14$

Thus the flooding velocity is

$Gf \quad = (0.14)\ (\rho_l\ \rho_{gc}) / (F\psi u_L^{0.2})^{0.5}$

$= \left((0.14)\ ((\rho_l\ \rho_{gc}) / (F\psi u_L^{0.2})) \right)^{0..5}$

$= \left(\frac{(0.14)(30)\ (62.4)(0.075)}{(160)\ (1)\ (1.8)^{0.2}} \right)^{0..5}$

$= \left(\frac{19.656}{(160)\ (1.124)} \right)^{0..5}$

$= 0.109^{0.5}$

$= 0.330$ lb/ft ^{2}/sec

The actual velocity is

$G\ act \quad = (0.6)(0.330)$

$= 0.198$ lb/ft ^{2}/sec

$= 712.8$ lb/ft ^{2}/hr

The tower diameter may now calculate directly from equation

$Dt \quad = (1.13)\ (S)^{0.5}$ when $S = q(acfm)/4$

$S \quad = 9245.9/60$

$= 154.09$

$= 154/4$

$= 38.5$

Dt $= (1.13)\ (38.5)^{0.5}$

$= 1.13 \times 6.20$

$= 7.006$ ft

The packing height = 17.00 ft and the tower column diameter =7.006 ft

From calculation base on the principle of this type of scrubber is to remove contaminants from the gas stream by passing the stream through a packed structure which provides a large wetted surface area to induce intimate contact between the gas and the scrubbing liquor. the contaminant is absorbed into or reacted with the scrubbing liquor.so minimum structure Packed Column, are

1) Spray nozzle is a device which distribute liquid over and trickle down. This spray nozzle is on the top of the packed tower in this case use Hollow Cone which distribute liquid in cycle shape

2) Column,tank and packing, media which packed media to provide a large surface area to contact gas ,high different and diameter for each foundry factory. Tank should preferred vender for corrosive and high temperature,various material of construction may be used to resist corrosive contaminant and scrubing liquor that come into contact with the unit such as homogeneous polypropylene tank,co polymer which a 25-year, corrosion-free service life. Each high-strength, low weight anodizing/plating tank is engineered for hard coat anodizing operations, where processing temperatures are in the 32°F range. The tanks are also suited to Type II ('hot' anodizing, 85°F and above) and other plating operations with temperature extremes and fluctuations. Other tank are stainless tank, roto-model tank also.

Figure 37 One type of tank

The packing of the tower is normally a proprietary loose fill random packing designed to encourage dispersion of the liquid flow without tracking, to provide maximum contact area for the 'mass transfer' interaction and to offer minimal back pressure to the gas flow. The reactivity between the contaminant and the scrubbing liquor influences the system designer's determination of gas and liquor flow and the height and diameter of the packed bed. Figure 36 show media type

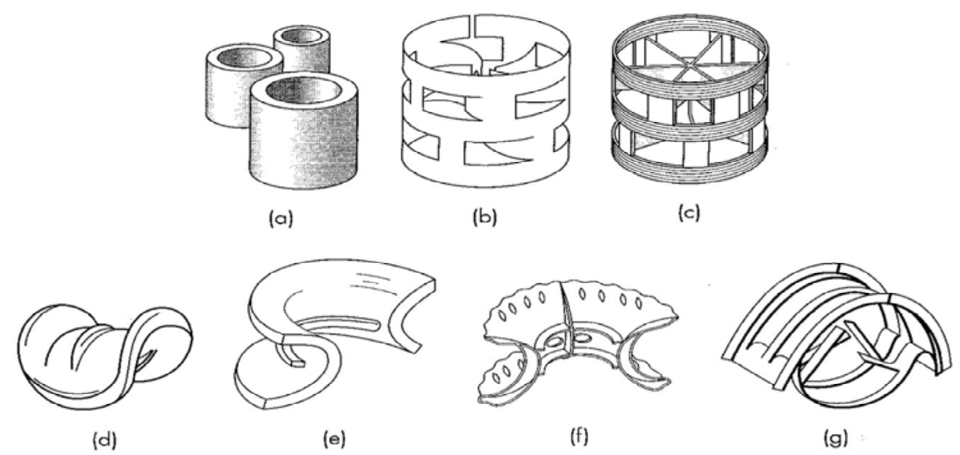


FIGURE 18.2
Common tower packings: (*a*) Raschig rings; (*b*) metal Pall ring; (*c*) plastic Pall ring; (*d*) Berl saddle; (*e*) ceramic Intalox saddle; (*f*) plastic Super Intalox saddle; (*g*) metal Intalox saddle.

Figure 38 Media type

Source: Theodore (1988)

3) A demister is fitted at the top of the tower to prevent entrainment of droplets of the scrubbing liquor into the extraction system or stack, An Engineer should design mist eliminators for ease of removal for inspection, cleaning and replacement.

4) Exhausting Fan wetted packed towers can be designed for very high efficiencies with relatively low capital and running costs. The low pressure drop associated with packed bed scrubbers permits the use of smaller more economical fans. Although efficiency may be affected, a packed tower will usually function when gas or liquor flows vary from its original design parameters. This fan will install at entrance of Air Pollution System before gas stream inlet. Usage fan consider from exhaust fan flow rate, static pressure, fan categories, material and accessories, direction but importance data is static pressure which calculate from

static pressure = (Duct stack pressure + Air pollution control system static pressure) X 30 % (Safety factor)

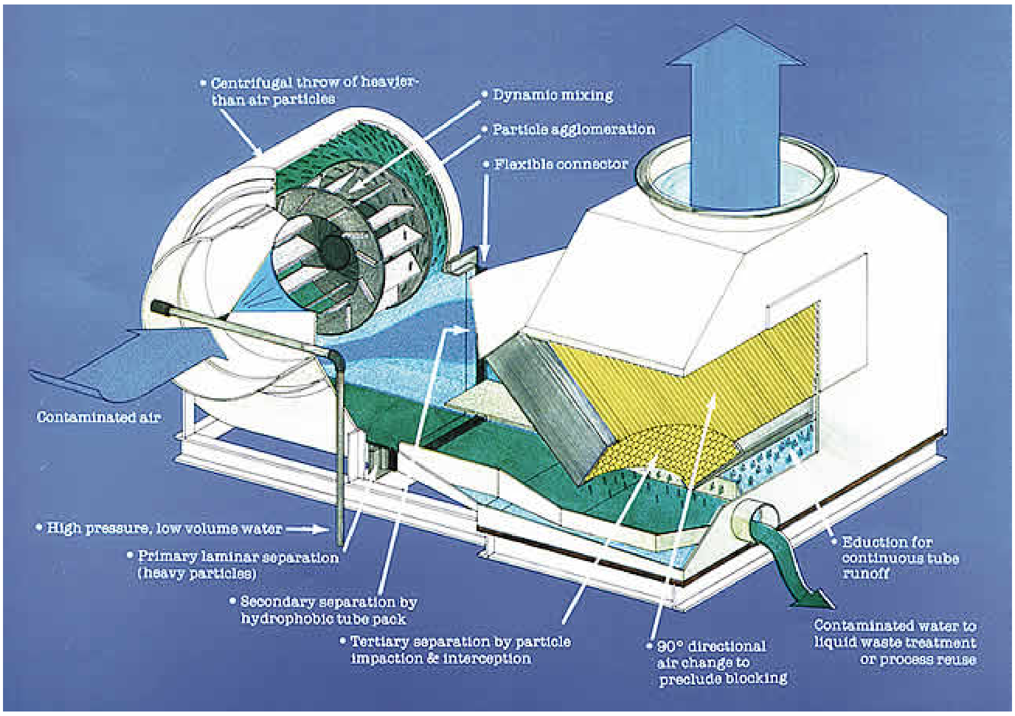


Figure 39 Circulating Fan

Source: TRI MER FAN CO.LTD.(2008)

Model No.	Capacity C.F.M.	Motor H.P.	A	B	C	D	E	F	G	H	I	Maximum GPM Required	Drain Size	Total Weight
F-S-⅓	50- 250	⅓	2'-8½"	1'	1'-4¾"	2'-1"	6"	1'-6½"	6"	2'-10⅝"	1'-6"	¼	1"	160
F-S-½	250- 500	1	3'-1½"	1'-½"	1'-6½"	2'-3"	8"	2'-1½"	9"	3'-4"	1'-9½"	¼	2"	180
F-S-¾	500- 1,000	1½	4'-2"	1'-4½"	2'-1½"	3'-½"	11"	2'-9½"	11"	4'-5½"	2'-4½"	½	2"	360
F-S-⅞	1,000- 1,700	2	4'-2½"	1'-7½"	2'-5½"	2'-11½"	1'-1"	3'-1"	1'-1"	4'-6"	3'-0"	½	2½"	425
F-S-1	1,700- 2,500	3	5'-5"	1'-10½"	2'-10½"	3'-10½"	1'-4"	3'-7½"	1'-4"	5'-8½"	3'-0"	1½	3"	615
F-S-2	2,300- 3,800	5	6'-2"	2'-2"	3'-5"	4'-3"	1'-7"	4'-3"	1'-7"	6'-6½"	3'-9½"	2	4"	770
F-S-3	3,400- 5,700	5	7'-5½"	2'-6½"	4'-½"	5'-2"	2'-0"	4'-7½"	2'-0"	7'-11"	4'-0"	3	4"	1,025
F-S-4	5,200- 6,900	7½	8'-7"	2'-8½"	4'-4½"	6'-0"	2'-2"	5'-4"	2'-2"	9-1½"	5'-5"	4	6"	1,190
F-S-5	6,000- 8,300	7½	8'-10"	2'-10½"	4'-8½"	6'-2½"	2'-4"	4'-11"	2'-4"	9'-6½"	5'-10"	5	6"	1,605
F-S-6	8,000- 10,300	15	9'-7"	3'-2½"	5'-3"	6'-7"	2'-8"	6'-2"	2'-8"	10'-3"	5'-3"	6	6"	1,875
F-S-7	10,000- 12,500	15	10'-2½"	3'-5½"	5'-8½"	6'-10½"	2'-11"	6'-4"	2'-11"	10'-11½"	6'-9"	8	6"	2,088
F-S-8	12,000- 15,300	15	11'-9"	3'-9½"	6'-3½"	8'-0"	3'-3"	7'-0"	3'-3"	12'-6"	6'-9"	9	6"	2,380
F-S-9	15,000- 18,600	20	12'-6"	4'-1½"	6'-10½"	8'-4"	3'-8"	6'-2"	3'-8"	13'-4½"	6'-9"	12	6"	2,930
F-S-10	18,000- 22,700	20	15'-9½"	4'-6"	7'-6½"	10'-3"	4'-0"	6'-11"	4'-0"	16'-9½"	6'-9"	14	6"	3,470
F-S-11	22,000- 27,500	25	16'-11½"	4'-10½"	8'-3½"	11'-2"	4'-5"	8'-0"	4'-5"	17'-10½"	6'-9"	17	6"	4,120
F-S-12	27,500- 37,000	40	20'-4"	5'-6½"	9'-3½"	13'-11"	5'-0"	8'-11"	5'-0"	21'-7½"	8'-0"	20	6"	4,630
F-S-14	37,000- 45,000	50	20'-11"	6'-1½"	10'-½"	14'-4"	5'-4"	10'-0"	5'-4"	22'-3"	9'-0"	24	6"	5,100
F-S-15	45,000- 60,000	75	24'-2"	6'-1½"	10'-1"	16'-6½"	5'-4"	11'-2½"	5'-4"	25'-7"	9'	30	6"	6,600
F-S-16	60,000- 80,000	100	31'-8½"	6'-7½"	11'-2½"	20'-5½"	5'-8"	11'-2½"	5'-8"	31'-8½"	9'-4½"	40	6"	8,300
F-S-17	80,000-100,000	125	33'-7"	7'-2⅝"	11'-11⅝"	20'-9½"	6'-2"	11'-2½"	6'-2"	33'-6⅝"	11'-4½"	50	6"	9,000

For double pack models check with manufacturer for dimensional data

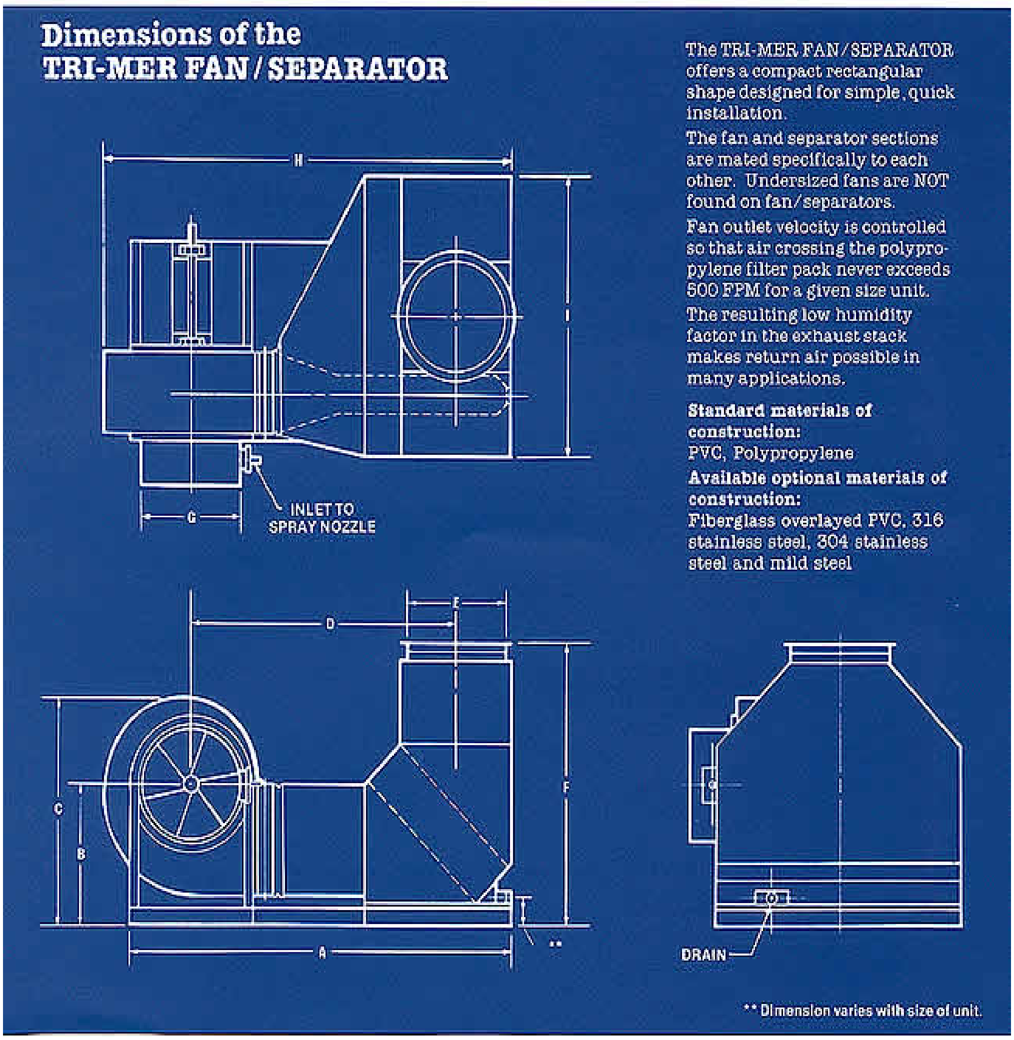


Figure 40 Dimensions of TRI MER FAN

Source: TRI MER FAN CO.,LTD.(2008)

5) Hood and piping exhaust pipe :consider on material which resistance corrosion ,high temperature.There are several types of hood such as enclosure hood, canopy hood. and capturing hood. The advantage of enclosure hood which different from canopy and capturing is to reduce turbulent and can use low pressure fan in system also.The preferred method of enclosure is total enclosure as its name indicates, total enclosure means the complete enclosure of a particular machine or operation and proper exhaust of the enclosure. The example of exhaust hood performance are Exterior 1,000-4,000 cfm, Basic enclosure 1,000-2,000 cfm and Enhanced 500- 1,500 cfm .

6) Circulating Pump is a device for conduct air and gas to air pollution control system. Improper Pump SizeTo determine pump size and selection for a given unit it is necessary to perform hydraulic calculations for the recirculation system. Three parameters affect the required design head of a pump: friction losses through piping and fittings, pumping height, and pressure loss of nozzles. If add-in items, such as basket strainers, are not accounted for in thedesign of a system the pump flow rate will suffer and this, in turn, can effect efficiency.Pump Logistics,Pumps that are subjected to adverse conditions due to location or water level can lead performance problems.
A low sump operating level can create vortexing and the pump will start to suck air, which will quickly deteriorate the volume and pressure of the pump.

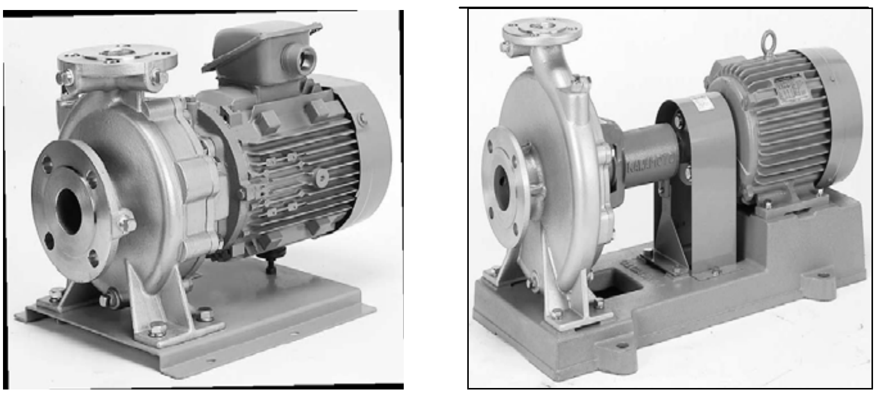


Figure 41 Pump type
Source: KAWAMOTO PUMP MFG.CO.,LTD (2008)

7) Duct to carry gas in air pollution control system,made of several material depend on usage like carbon steel duct or PVC for high temperature and corrosive resistant.water cool use for reduce fluid temperature, stainless steel duct,carbon steel duct and etc. For example,Spiral Duct pressure class in WG (Pa) are positive + 10 inc WG (2005) and Negative -4" WG (1000) ,Stream Type Permitted are RL-5 can use in air pollution control system, ventilation system, air duct,made of galvanize an other one is flexible duct can use in industrial work widely to joint with other past, figure 40 show this 2 duct type.

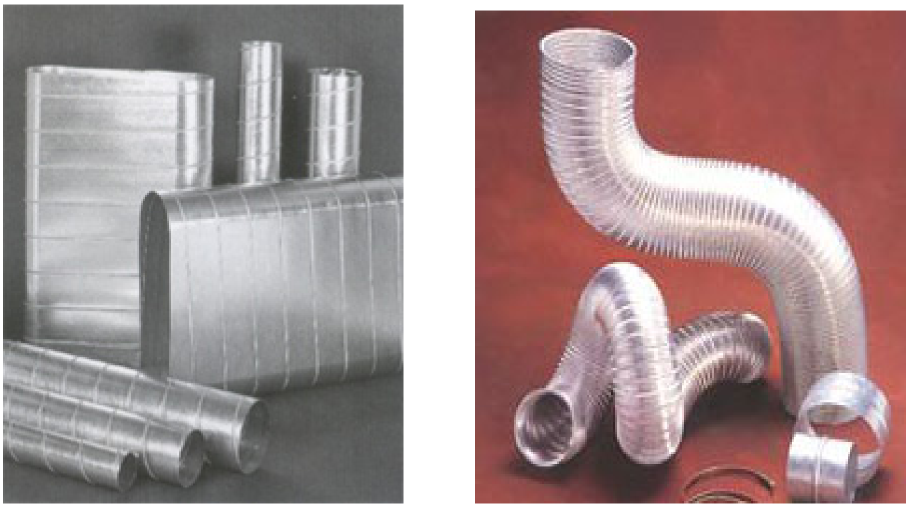


Figure 42 Duct type
Source: JSV THECHICAL CO.LTD.,(2008)

8) Mist eliminators are typically employed to remove liquid mist or liquid particles from a gas stream in which liquid has been suspended or entrained. Mist eliminators may be employed in a wide variety of devices where there are gas-liquid contacts and are particularly used for the cleaning of waste or flue gas streams in a wet scrubber or other applications. In such processes, mist eliminator devices are provided in one or more layers across a gas-liquid contacting column or duct to remove the mist from the gas to provide a mist-lean gas stream from a mist-rich gas. Mist eliminator blades should be encapsulated in boxes to prevent potential by-pass.

Mist eliminators may comprise a wide variety of different structures; however, one very popular type of mist eliminator comprises a baffle-type or chevron-type mist eliminator which is arranged in one or more layers and provides for a zigzag or a tortuous flow path through the generally parallel, spaced-apart, mist eliminator baffles, with the baffles generally having an upstream and a downstream edge and arranged horizontally within the gas-liquid column or chamber, although they may assume other sloped positions, and vertical positions.

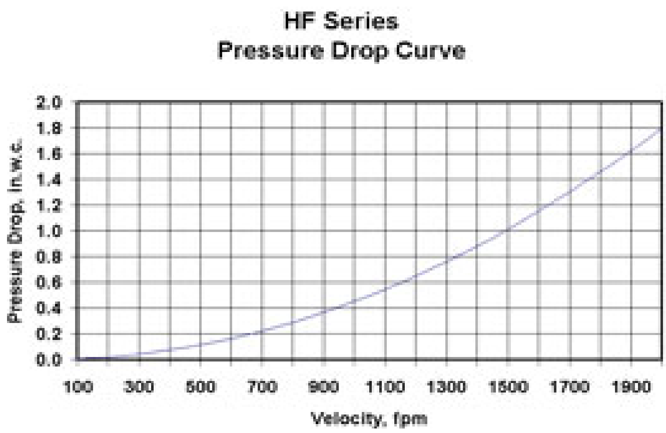


Figure 43 Mist eliminators and its pressure drop curve

Source: ALGILIS HOMPAGE (2008)

Example Characteristic from calculation foundry factory No.3

1. Configuration:Vertical (Counter Current) Round Vessels
2. L/G Ratio:1.3 to 2 gpm/1000 cfm
3. Air Distribution Enhancement:Use Packing Support Beams as turning veins for proper air distribution
4. Liquid Distribution , Overflow Weirs with V-Notches (min. 12 drips points/ft2)
5. Mist Eliminator ,Chevron Type 99% efficiency greater than 10 micron
6. Mist Eliminator Velocity, 800 fpm for high efficiency
7. Material of Construction .homogeneous Polypropylene or co polymer tank

Cost estimation, need consider the budget for construction these air pollution control system in this study it seem high cost, direct costs i.e. absorber, packing and auxialilary equipment (EC),In stall foundation and support ,duct system wages ,maintenance cost and indirect annual cost also.

Foundry Factory No.3

Direct Cost

Tank, Absorber, packing and auxiliary equipment (EC)	=	100,000 BAHT
- Equipment usage and operate	=	0.1 *EC
	=	10,000 BAHT
- Tax	=	0.03*EC
	=	3,000 BAHT
- Loading	=	0.05*EC
	=	5000 BAHT
- Potential Equipment Cost(PEC) = 1.18*EC	=	118,000
Install System		
- Foundation and support	=	0.12* PEC
	=	14,160
- Construction	=	0.40*PEC
	=	47,200
- Electric works	=	0.01*PEC
	=	1180
- Duct and painting	=	0.32*PEC
	=	37,760
Total	=	100,300
Total Direct Cost	=	218,300

Indirect Cost

-	Structure system	=	0.02*PEC
		=	2,360
-	Engineer and foreman wage	=	0.01* PEC
		=	1,180
-	Start up and efficiency system test	=	0.02*PEC
		=	2,360
-	Future trouble and others	=	0.03*PEC
			3,540
Total	Indirect Cost	=	9,440
TOTAL		=	227,740 BAHT
Total maximum		about 300,000 BAHT	

This rate is basis minimum rate it not yet include direct annual cost and indirect annual cost also.

Wet scrubbers are used for abatement of waste gases from semiconductor manufacturing process tools and related equipment. Many wet scrubbers in operation are achieving less than expected emission results and many require frequent shutdown due to problems that

1) Inadequate Sump Fluid Replenishment for scrubbers using overflow or blow down to maintain fresh solution, the fresh water make-up rate must be adequate to maintain the concentration gradient between the liquid and gas phase. The concentration gradient for a given unit is dependent upon a number of variables and if not maintained the efficiency of a system can drop quickly and significantly. In some cases, if the gradient is lost, contaminants can be stripped from solution.Two techniques for sump replenishment are overflow and blowdown with the overflow method being more common and simple to operate with no instrumentation other than a rotometer. Fresh water is added through an adjustable flow meter at a continuous rate while the sump liquid overflows into the scrubber drain at a predetermined

location. In the blowdown method, liquid is forced to drain by the recirculation pump. If blowdown is inadequate, the rate of scaling and algae growth will increase. sedimentation will also increase. Sump level controls and solenoid valves or flow control valves have to be provided in the recirculation piping to allow fluid to be discharged at a determined rate. In either method, the make-up water rate must be greater than the “to drain” rate due evaporation losses which can be from 2 to 4 gpm depending on weather conditions and operating temperatures. This is the key point for keeping the concentration gradient in check.

2) Channeling Caused by Plugged Spray Nozzles,Spray nozzles can be an operator’s nightmare and the cause of frequent and expensive unplanned shutdowns. Plugging should be expected when using scrubbers that incorporate spray nozzles. When a nozzle plugs, the area of packing directly below is not receiving liquid. This will create an area where no absorption is taking place and therefore decreases the efficiency of the scrubber.

3) Channeling Caused by Poor Air Distribution and Rectangular Housings
In vertical scrubbers, inlets are located 90 degrees from air direction through the packed tower. The incoming air stream must make an abrupt 90-degree turn into the packing.Very few scrubbers are designed to account for this abrupt turn. Air follows the path of least resistance. Air will continue straight through the inlet to the back wall of the vessel where it is disturbed and will spiral and vortex up through the packed bed section. This channeling creates dead spots within the packed bed. The now channeled air streams will pass through the packed bed at higher velocities below the designed retention time.Air will also follow the same general undisrupted path through rectangular scrubber housings. Dead spaces are common in rectangular vertical and horizontal scrubberhousings. Design for these units must also account for air

4) Biological Growth ,Build-ups of biological growth in packed bed sections and mist eliminators will adversely affect performance of scrubbers. In acid scrubbers, where pH is typically maintained in the 8 to 9 ranges, biological growth is a

commonality.Without treatment, the growth can create areas of channeling and increase the pressure drop through the scrubber.

From above problem which cause air pollution control system low efficiency so a suggested maintenance check list are pump maintenance,fanmaintenance,absorber maintemance and system maintenance also.

3.2 Improvement The Present Air Pollution Control System

From the physical properties of those three foundry factory's air pollution system, spray tower, the simpliest type of scrubber, the researcher found that some of equipment in air pollution control system were damage and not ready to work. Mostly its hood and spray nozzles were plugged and could not spray water to capture particles suspended in the gas stream which related to high level of CO and TSP emission. To resolve this condition it needs emergency repair or even the replacement if necessary and also the annual system checking program by the owner or the technician who operate the pollution control system. The program should include a regular inspection as listed below

1. Checking the corrosion and leaks in line and vessel.
2. Checking the static pressure drop, liquid flow rate, a liquid seal which causes entrainment or plugging and instrumentation malfunction.
3. Checking turbidity and pH of liquid especially in SO_2 removal process
4. Replace or rebuilt a new equipment instead damage one

Some factories required a higher liquid to gas ratio to increase the collecting efficiency for both TSP and PM_{10} because the typical gas flow rate for spraying, 1 - 47 m^3/s , and between 7-10 gallon/1,000 ft^3 is optimal performance liquid flow rate. Increasing liquid pressure (H), high liquid pressure can make a fine water spray and increase amount of impaction which related directly with spray tower's efficiency a drainage wastewater or liquid in system is necessary since it was in saturated situation and was reused in circle system much time so the efficiency of adsorption pollutant in gas stream will decrease too,for fine PM applications require high liquid to gas ratios (over 20 gallons per 1000 cubic feet)

Other methods for mitigating the potential adverse effect of SO_2 emission are using tall stack (may be does not effective) intermittent control by loadding or fuel switching and coal-cleaning techniques, optimum fresh air (O_2) ratio in combustion will increase TSP and CO efficiency also.

From these study, discussion may be mention on 2 items this following

1. Air measurement result both on community, out side door and in compliant's house 2 site, Bangkhae school there are some result may be interfere by emitted from vehicles road especially in compliant 's house due to its locate roadside ,main Phetkasem Road so may be necessary to measure a traffic pollutants for a complete result of this study and about toxic gas on community which found that there are high concentration level (SO_2) even thought it was the day with out foundry factory working it means next study should identified other source of SO_2 which emitted pollutant and caused to high concentrate level continuously and conduct to resolve this real situation but how ever both air measurement remain stand on rather accuracy result because it base on standard scientific instruments and science principle also.

2. Redesign air pollution control system, packed tower instead present air pollution control system: spray tower is only a basis design in this case some facility need more detail for apply with other foundry industries and some input data was assume base on theory due to incomplete data so in practice way some data need to study closely real condition to complete and high capacity of system.

CONCLUSION AND RECOMMENDATIONS

The Effects of Foundry Industries emission to Community in Bangkok can be concluded that the emission from Foundry Factories have in trended to be a nuisance in Phetkasem 51 Road community even though the factories have been trying to improve their air pollution control system already due to the problem of the air pollution control system, the damage of the spray tower and the lack of knowledge of workers who operate air pollution control system, so this study present a solving way 2 parts are

Firstly, to repair the present air pollution control system ,spray tower parts, such as the broken hood ,league conduct ,inspecting program to check every device every day and to increase pollution control system's efficiency by increase liquid pressure ,liquid/gas ratio and always change a saturated status liquid including the optimal air and fuel ratio will increase efficiency of produce air pollutant (CO,TSP,PM-10)

Secondly, to redesign a air pollution control system for the foundry factory which emit pollutant over standard 3 foundry factory, Packed Column. It's advantage for remove SO_2 due to it use media to capture pollutant in gas stream and dust in same way in this study a redesign pack column seem high investment may be it does not possible for small enterprise.

However since second way is better to solve the problem but when consider about the budget that needed to install it might not happen easily therefore resolve this problem are compromise and cooperate between foundry factory 'owner to maintain their device like the first way and improve their process while people in Phetkasem Road community has awareness about air pollution control include a government agency always inspect and strong enforce regulation also.

Recommendation for Future Work

From conclusion as previous ,a new air pollution control system;packed tower does not possible in economic policy due to it need high cost to construction a system but it can use to treat gases in other industrial source which release SO_2 and acid gas even though it can apply to foundry factory in other area of Bangkok such as Chomthong, Bangkhunthain district by addition more detail and try to reduce investment cost to apply it in real situation,update to meet a regular so an ideal air pollution control system should be advantage this following

1. Smaller tower diameters, small footprint
2. Lower pressure drop
3. Smaller recirculation pumps ,smaller blower motors 30-50% higher capacity Lower fan power costs, less noise
4. Reduced equipment and operation costs
5. Smaller Mist Eliminators
6. Less packing volume lower cost packing may be made of specialty plastics
7. Fouling and plugging resistant and reduced maintenance costs

.

Figure 43 Special media type

Source: Lantec Products Inc.(2008)

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APPENDIXS

Appendix Table A[1] Foundry Factory No.1 Stack 's Description

Order	Description	Unit	Result
1.	Diameter	m	0.22
2.	Shape	-	Circle
3.	Stack Temperature	˚C	40
4.	Gas Velocity	m/s	11.32
5.	Air Velocity	M^3/s	0.2
6.	Moisture	%	2.18
7.	O_2 Rate	%	10.2
8.	CO_2 Rate	%	6.9
9.	Absolute Stack Pressure	mm.Hg	760

Appendix Table A[2] Foundry Factory No.3's Stack Description

Order	Description	Unit	Result
1.	Diameter	m	0.20
2.	Shape	-	Circle
3.	Stack Temperature	˚C	62
4.	Gas Velocity	m/s	14.69
5.	Flow rate	Nm^3/s	1389
6.	Moisture	%	5.1
7.	Atmospheric Temperature	˚C	37
8.	Barometric Pressure	mm.Hg	754

Appendix Table A[3] Foundry Factory No.4's Stack Description

Order	**Description**	**Unit**	**Result**
1.	Diameter	m	0.76
2.	Shape	-	Circle
3.	Stack Temperature	˚C	49
4.	Gas Velocity	m/s	12.44
5.	Flow rate	Nm^3/s	13851
6.	Moisture	%	5.4
7.	O_2	%	18.8
8.	Atmospheric Temperature	˚C	38
9.	Barometric Pressure	mm.Hg	761