Estimation of Public Health Impacts of Major Thermal Power Plants in Pakistan: An Application of SIMPACTS

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Objectives

- Estimation of damages of human health due to atmospheric emissions of five major thermal power plants of Pakistan
- Assessment of possibilities to reduce the damages of human health

Methodology

QUERI module of the SimPacts model was used to estimate the health impacts

Power system of Pakistan

Source	Installed capacity on 30th June 2001		Electricity generation during 2001	
	MW	Share in total capacity (%)	GWh	Share in total generation (%)
Hydro	4,826	27.6	17,194	25.2
Oil and Gas	12,020	68.9	48,684	71.5
Of which				
BQTPP	*1,260*	*7.2*	*6,267*	*9.2*
HUBCO	*1,292*	*7.4*	*7,165*	*10.5*
GTPP	*1,655*	*9.5*	*7,09*	*10.4*
KAPCO	*1,500*	*8.6*	*6,139*	*9.0*
MTPP	*1,350*	*7.7*	*5,912*	*8.7*
Coal	150	0.9	241	0.4
Nuclear	462	2.6	1,997	2.9
Total	17,458	100	68,117	100

40.4%

47.8%

Stack parameters

	BQTPP	HUBCO	GTPP	KAPCO	MTPP
Size (MW)	1,260	1,292	1,655	1,500	1,350
Technology	Steam	Steam	Steam & C.C.	C.C.	Steam
Stack height (meters)	93.3	200	100	150	200
Stack diameter (meters)	10.53	13	10	10	8.43
Exit flow velocity (m/s)	13.0	9.78	31.9	28.9	21.8
Exit temperature (K)	433	420	364	364	427

Depletion velocities

- For Pakistan, data for depletion velocities are not readily available
- Some studies are available showing results (concentration) of dispersion models applied for air emissions from power plants in Pakistan (Environmental Impact Studies).
- The studies are for SO_2 and NOx only

Depletion velocities (contd..)

Depletion velocities (k) of SO_2 and NOx were determined with help of their concentration data and the following equation.

$$C = \frac{Q}{2\pi\, uhr}\, e^{-kr/uh}$$

Where C is concentration in _g/m3, Q is pollutant emission in _g/second, *h* is mixing height in meters, *r* is distance in meters, *u* is wind velocity in meter per second and *k* is depletion velocity in meters per second

Depletion velocities (contd..)

Depletion velocities of PM10, Sulphate and Nitrate were estimated with the help of following correlations

Correlation coefficients among depletion velocities, wind speed and precipitation rate based on data in Spadaro [2002]

	PM_{10}	SO_2	NO_x	Sulphate	Nitrate	Wind speed	Precipitation
PM_{10}	-	0.78	0.19	0.85	0.82	0.14	0.78
SO_2	0.78	-	0.04	0.74	0.48	0.18	0.33
NO_x	0.19	0.04	-	0.52	0.25	0.43	0.33
Sulphate	0.85	0.74	0.52	-	0.75	0.20	0.72
Nitrate	0.82	0.48	0.25	0.75	-	0.56	0.78
Wind speed	0.14	0.18	0.43	0.20	0.56	-	0.33
Precipitation	0.78	0.33	0.33	0.72	0.78	0.33	-

Depletion velocities (centimetres per second)

Power Plants	PM_{10}	SO_2	NO_x	Sulphate	Nitrate
GTPP, MTPP and KAPCO	2.11	2.0	2.24	3.49	1.31
BQTPP & HUBCO (Data of Karachi)	1.64	1.55	1.74	2.71	1.02

Exposure Response Functions

Health Impact	Pollutant	Receptor Group	IRR (per Ég/m³)	F_{pop} (fraction)	Incidence rate (cases/ year)	YOLL per Case	Baseline rate (cases or YOLL / year)	ERF Slope (cases or YOLL/year-Ég/m³)
Long-term Mortality	PM_{10}, Nitrate	Age >30 years	0.0046	0.29	12.7E-03	11	0.04	1.84E-4
	Sulphate	Age >30 years	0.00768	0.29	12.7E-03	11	0.04	3.08E-4
Short-term Mortality	SO_2	Entire Population	4.6E-04	1.0	9E-03	0.5	0.045	2.07E-06
	NO_x	Entire Population	3.39E-04	1.0	9E-03	0.5	0.045	1.54E-06
Respiratory Hospital Admissions	PM_{10}, SO_2, Nitrate	Entire Population	4.0E-04	1.0	0.0053	n.a	0.0053	2.12E-06
	Sulphate	Entire Population	6.68E-04	1.0	0.0053	n.a	0.0053	3.54E-06
	NO_x	Entire Population	2.2E-04	1.0	0.0053	n.a	0.0053	1.17E-06

Exposure Response Functions (contd..)

Health Impact	Pollutant	Receptor Group	IRR (per Ég/m³)	F_{pop} (fraction)	Incidence rate (cases/ year)	Baseline rate (cases or YOLL / year)	ERF Slope (cases or YOLL/ year-Ég/m³)
Cardiovascular Hospital Admissions	PM_{10}, Nitrate	Age > 65 years	1.0E-03	0.035	0.0047	0.00016	1.65E-07
	Sulphate	Age > 65 years	1.67E-03	0.035	0.0047	0.00016	2.75E-07
Chronic Bronchitis	PM_{10}, Nitrate	Age > 18 years	2.14E-02	0.504	0.0033	0.00166	3.56E-05
	Sulphate	Age > 18 years	3.57E-02	0.504	0.0033	0.00166	5.94E-05
Working Days Lost	PM_{10}, Nitrate	Employed Population	9.5E-03	0.28	0.35	0.098	9.3E-04
	Sulphate	Employed Population	1.59E-02	0.28	0.35	0.098	1.56E-03

Unit damage costs in US $ of 2000

Health Impacts	Unit Damage Costs		Estimates for costs of illness (COI)
	ExternE	Pakistan*	
Short-term Mortality (YOLL)	174,000	14,182	7,100**
Long-term Mortality (YOLL)	101,000	8,232	4,100**
Respiratory Hospital Admission (RHA)	4,540	370	120
Cardiovascular Hospital Admission (CVHA)	17,600	1,434	920
Chronic Bronchitis	177,800	14,491	4,700
Loss of Working Day	116	9.5	5

*** ExternE data adjusted by GDPppp of Pakistan**

**** these are not COI values. These values of YOLL are from a survey conducted by the working team.**

Findings of the study
(Results of the Model)

Health damage costs of power plants in year 2001

	BQTPP	HUBCO	GTPP	KAPCO	MTPP
By GDPppp adjustments					
Total (million US dollars)	44.5	59.1	6.1	16.3	39.9
Cents/kWh	0.71	0.83	0.09	0.27	0.68
By Cost of Illness					
Total (million US dollars)	20.2	26.9	2.8	7.3	18.1
Cents/kWh	0.32	0.38	0.04	0.12	0.31

Public health damage by impacts

	BQTPP	HUBCO	GTPP	KAPCO	MTPP
Million US dollars	44.5	59.1	6.1	16.3	39.9
Contribution by impact					
Long-term Mortality	73.6%	73.6%	73.7%	73.8%	73.6%
Short-term Mortality	1.3%	1.3%	1.1%	0.9%	1.3%
Chronic Bronchitis	25.1%	25.1%	25.1%	25.1%	25.1%
C.V.H.A.	ng.	ng.	ng.	ng.	ng.
R.H.A.	0.1%	0.1%	0.1%	0.1	0.1%
W.D.L.	ng.	ng.	ng.	ng.	ng.

ng. negligible

Note: Costs are in year 2000 prices

Public health damage by pollutants

	BQTPP	HUBCO	GTPP	KAPCO	MTPP
Million US dollars	44.5	59.1	6.1	16.3	39.9
Contribution by pollutant					
PM_{10}	0.6%	0.6%	1.6%	1.3%	0.7%
SO_2	1.1%	1.2%	0.3%	0.6%	1.1%
NO_x	0.2%	0.1%	0.8%	0.4%	0.2%
Sulphate	73.1%	75.3%	47.7%	37.4%	70.4%
Nitrate	25.0%	22.7%	49.5%	60.4%	27.6%

Sensitivity Analysis

Sensitivity analyses were performed to study the effects of:

- stack height,
- fuel switching, and
- depletion velocities

Impacts of Stack Height

Sensitivity analysis were performed by changing the stack heights, for each of the power plant, in the range of 75 meters to 250 meters by a step of 25 meters. It was found that:

- change of stack heights of GTPP and KAPCO do not affect the damage costs caused by these plants.
  - Both emit small quantities of PM10.
  - Both plants are located in rural areas. Damages of SO2 and NOx are insignificant compared to damages of sulphate and nitrate. Sulphates and nitrate are formed from their precursors and their damages are independent of stack heights.
- Increase in stack heights decrease the human health impacts of BQTPP, HUBCO and MTPP.
  - Damages of BQTPP remained constant beyond 200 meters stack heights.
  - Health costs of HUBCO continuously decreases beyond study limit of 250 meters. But, after 200 meters, impacts of increasing stack height were insignificant for HUBCO

Impacts of fuel switching on health damage costs (cents/kWh)

	Fuel mix of year 2001	100% HSFO	100% LSFO	100% Natural Gas
BQTPP	0.71	0.85	0.39	0.11
HUBCO	0.83	0.83	0.37	0.11
KAPCO	0.27	1.0	0.45	0.11
MTPP	0.67	0.97	0.44	0.12

GTPP is not included as it already working on natural gas

Impacts of depletion velocities

It has been found that human health damage costs of BQTPP and HUBCO are decreased by 23% by using the same depletion velocities as used for the MTPP, KAPCO and GTPP.

CONCLUSIONS

- Atmospheric emissions of the thermal power plants adversely affect the human health, particularly in the form of Long-term Mortality and Chronic Bronchitis.
- The human health damages caused by five major thermal power plants of Pakistan are US$ 166 million which are about 39% of total public sector expenditure for the health sector. These damages can be as high as 626 million US dollars -- 147% of the public health sector expenditures of the country.
- Reduction in damage costs through increase of stack height is marginal in case of BQTPP, HUBCO and MTPP. Increase in stack height is ineffective in case of KAPCO and GTPP.
- Use of cleaner fuels (LSFO and Natural Gas) can reduce upto 80% of human health damages.